# **Ecology of the Asian clam, *Corbicula fluminea* (Müller), and its impact on the benthic invertebrates in Guajataca and La Plata reservoirs, Puerto Rico**

by

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## Abstract

*Corbicula fluminea* (Müller, 1774) is one of the most invasive freshwater bivalves. It is non-native to America, where it has impacted the benthic macroinvertebrates and phytoplankton communities of many lakes. The first report of this species in Puerto Rico was from Cayey River in 1998. By 2000, populations estimated at 10 individuals/$m^2$ were reported at La Plata and Cidra reservoirs. Since 2001, this species and its effect on the benthic macroinvertebrates have not been monitored. The *C. fluminea* populations in Guajataca and La Plata reservoirs were sampled three times during early Spring of 2011. Samples were taken with an Ekman dredge at Lacustrine, Transitional, and Riverine stations, at depth ranging 0-6 meters. Samples were sieved through 0.5 mm, preserved and transported to the laboratory for analysis. Benthic invertebrates were counted and identified to the lowest possible taxonomic level. The relative abundance of *C. fluminea* in both reservoirs was <5% of the total benthic macroinvertebrates. The estimated mean density of *C. fluminea* was 1,754/$m^2$ in Guajataca Reservoir and 204/$m^2$ in La Plata Reservoir. Most of the individuals were small and juveniles (less than 13 mm). The benthic macroinvertebrate communities in both reservoirs were dominated by the gastropod *Tarebia granifera* and the entoproct *Urnatella gracilis*. This is the first systematic and ecological study on the zoobenthic community of reservoirs conducted in Puerto Rico and sets a baseline for future studies in reservoirs of the Island.

# Resumen

*Corbicula fluminea* (Müller,1774) es uno de los bivalvos de bivalvos de agua dulce más invasivos. No es nativo de América, dónde ha impactado las comunidades de macroinvertebrados bénticos y fitoplancton de muchos lagos. El primer reporte de esta especie en Puerto Rico fue para el Río Cayey en 1998. En el 2000, las poblaciones se estimaban en 10 individuos/$m^2$ para los embalses La Plata y Cidra. Desde el 2001, esta especie y sus efectos en los macroinvertebrados bénticos no han sido monitoriados. Las poblaciones de *C. fluminea* en los embalses Guajataca y La Plata fueron muestreadas por tres ocasiones durante principios de la primavera de 2011. Las muestras se tomaron con una draga Ekman en las estaciones Lacustrina, Transicional y Riparia a profundidades de 0-6 metros. Las muestras fueron cernidas con tamiz de 0.5 mm, preservadas y transportadas al laboratorio para su análisis. Los invertebrados bénticos fueron contados e identificados al nivel taxonómico más bajo posible. La abundancia relativa para *C. fluminea* en ambos embalses fue <5% del total de macroinvertebrados bénticos. La densidad promedio de *C. fluminea* para el embalse Guajataca fue 1,754/$m^2$ y 204/$m^2$ para La Plata. La mayoría de los individuos eran pequeños y juveniles (menos de 13 mm). La comunidad de macroinvertebrados en ambos embalses fue dominada por el gasterópodo *Tarebia granifera* y el entoprocto *Urnatella gracilis*. Este es el primer estudio sistemático y ecológico de la comunidad zoobéntica en los embalses de Puerto Rico y forma la base para estudios futuros en los embalses de la Isla.

"To my daughter Andrea Isabel;

because you inspire me to be the best day after day."

Love, Mami

"To my husband Angel Keith;

for having been patient with me. I know it wasn't easy."

Love, Ana

"To all those who have hauled an Ekman by hand from 50 m in a small boat on a windy day to find a stone cought between the jaws."

Brinkhurst, 1974

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*"God, thanks for putting the right people on my way."*

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# Introduction

The Asian clam, *Corbicula fluminea* (Müller), is a bivalve of the family Corbiculidae. Is native to Southeast Asia and it was introduced to North America in the early twentieth century by Asiatic immigrants as a food source (McMahon, 2001). Several authors attributed its introduction to the discharges of ballast waters of trade ships from Asia (Cohen and Carlton, 1998; Ricciardi and Rasmussen, 1998). Through anthropogenic activities it has become the exotic bivalve with the biggest distribution in Americas (McMahon, 2001). This organism alters the structure of the benthic community, impacting the biomass and density of other macroinvertebrates in the littoral zones of the freshwater systems (Vaughn and Spooner, 2006; Werner and Rothhaupt, 2007; Sousa et al., 2008b). Once present in the sandy bottoms of the freshwater habitats, it becomes an ecosystem engineer, allowing the density of other organisms, such as mayflies and leeches, to increase (Werner and Rothhaupt, 2007). In contrast, its high filtering rate alters the composition of the phytoplankton and, thus, reduces the densities of native mussels by limitating food resources (Vaughn and Spooner, 2006). The short life span, fast growth, early sexual maturity, high fecundity and natural dispersion are some of the characteristics that help *C. fluminea* to be such a successful invader of freshwater systems (McMahon, 2001; Sousa et al., 2008b). However, environmental factors like dissolved oxygen, emersion, pH, and water temperature are known to limit the success of this species (McMahon, 2001).

In Puerto Rico, the Asian clam was reported for the first time in 1998, from the Cayey River (Williams et al., 2001). In 2000, it was found at a density of 10 individuals per square meter in La Plata and Cidra Reservoirs (*Ibid*). Since then, the populations of *C. fluminea* and their effects on the benthic communities have not been monitored in the freshwater systems of the Island.

Due to the lack of local information about this species and its possible impacts on the benthic macroinvertebrate communities, the present study was conducted. Its main aims were to study the distribution and ecology of *C. fluminea* and to describe the associated benthic macroinvertebrate communities in two reservoirs in Puerto Rico with differing trophic status. Two of the largest reservoirs of Puerto Rico were selected: Guajataca and La Plata. Guajataca Reservoir is considered mesotrophic and, since none of the reservoirs in Puerto Rico is oligotrophic, it has the lowest trophic state on the Island. On the other hand, La Plata Reservoir is classified as hypereutrophic. The present study provides baseline information for future research on *C. fluminea* and represents the first comprehensive study about the long neglected zoobenthic communities of our water reservoirs.

# Objectives

The principal objectives of this study were to:

1. Estimate the densities of *C. fluminea* in La Plata and Guajataca reservoirs.
2. Characterize the preferred sediment type for *C. fluminea* in both reservoirs.
3. Determine the spatial distribution of *C. fluminea* along a hydrologic gradient (Riverine, Transition and Lacustrine sections) for La Plata and Guajataca reservoirs.
4. Characterize the benthic macroinvertebrates communities associated with *C. fluminea* at La Plata and Guajataca reservoirs.
5. Compare the community ecology of macroinvertebrates from Guajataca and La Plata reservoirs in relation with its throphic levels.

# Literature Review

Background

*Corbicula fluminea* was introduced to North America in early 1930 by Asian immigrants as a food source (McMahon, 2001). The first report of *C. fluminea* for the United States was in 1938 in the Columbia River in Washington State. The Asian clam distribution has spread over North America, to Hawaii, and even to Mexico (Karatayev et al., 2005). In 1981, it was reported for the first time from South America, specifically from La Plata River in Argentina (Darrigan, 2002). Scientists argued that *C. fluminea* could have been introduced to this South American freshwater system in the 1970's (Darrigran, 2002; Sousa et al., 2008a). In Puerto Rico, the presence of *C. fluminea* was first reported from the Cayey River in 1998. In 2000, densities of 10 individuals per square meter were reported for La Plata and Cidra reservoirs (Williams et al., 2001).

The dispersion of this species occurs both in natural and anthropogenic ways. The juveniles can be transported by water currents (McMahon, 2001). However, many anthropogenic activities like aquaculture, recreation, transportation from boats used in various freshwater systems without cleaning and the utilization of *C. fluminea* as fishing baits have promoted the colonization of other water systems (Cohen and Carlton 1998; Sousa et al., 2008a).

## Habitat

According to Sousa et al. (2008a) the Asian clam colonizes well oxygenated littoral zones with a dissolved oxygen range from 8.6- 11.1 mg/L. In contrast to Sousa's study, Nguyen and Pauw (2002) studied all watercourses of Flanders, Belgium, and found that the highest densities of *C. fluminea* were in the locations with the lowest dissolved oxygen concentration (45% saturation at about 4.0 mg/L). This species is found in lotic and lentic systems but can be more abundant in rivers (315-3206/$m^2$) than in reservoirs (30-796/$m^2$) (Karatayev et al., 2005). Asian clams preferred coarse and fine sandy substrates (Sousa et al., 2008; Cooper, 2007). The study in Lake Nacogdoches (Karatayev et al., 2003) demonstrated that clams were most abundant on sediments formed by shells and coarse detritus. Also, live clams were found at depths ranging from 0-4 meters. The highest density of *C.fluminea* was found at 1 m, and the highest biomass of the species was observed at 2 meters. These clams avoid colonizing areas with macrophytes because the oxygen levels in the sediments there are critical for this species (*Ibid*).

## *Corbicula fluminea* and benthic invertebrates

The establishment of invasive bivalves can affect the structure of the benthic habitat and community processes (Werner and Rothhaupt, 2007; Sousa et al., 2008b). Once the Asian clam becomes established in a new freshwater system, it usually dominates the benthic community (McMahon, 2001). According with Karatayev et al. (2003), *C. fluminea* accounted for 97% of the total mass in the macroinvertebrates communities of littoral zones. The dominance of this species in the benthic community is propelled by several biological characteristics: *Corbicula fluminea* has (1) a short life span 1-4 years; (2) fast growth; an adult can reach 50-70 mm, but just in the first year the shell can grow 15-30 mm; (3) early sexual maturity at 3-6 months; (4) is a simultaneous hermaphrodite; and (5) can produce 97-570 juveniles in each reproductive period (McMahon, 2001). When food sources are limited in the water column, the adult of *C. fluminea* can switch from filter feeding to pedal feeding to collect buried organic matter from the sediments (McMahon, 2001; Vaughn and Hakenkamp, 2001).

The presence of this species has negative effects on the populations of native bivalves. In fact, Sousa et al. (2007) indicated that native mussels in Spain and Portugal are being replaced by *C. fluminea*. The Asian clam displaces and reduces habitat for juvenile unionids and sphaeriids, by burrowing and bioturbation activity (Spooner and Vaughn, 2006). The high filtration rates of *C. fluminea* limit the availability of suspended food for other bivalves (Vaughn and Hakenkamp, 2001). Also, there is evidence that *C. fluminea* adults may ingest newly metamorphosed juvenile mussels and glochidia (Yeager et al., 1999). In contrast, Karatayev et al. (2003) found that in Lake Nacogdoches unionids and *C. fluminea* were both abundant and occupied the same areas. The depth distribution was overlapping, and both were abundant in the same type of substrate.

Bivalve activities such as shell production, filter feeding and bioturbation can result in ecosystem engineering processes affecting ecosystem structure and functions (Sousa et al., 2009). The introduction of shells to the benthic habitat promotes the establishment of sessile organisms like algae, sponges, insect larvae and other bivalves that are usually unable to establish on bare mud or sand (Gutiérrez et al., 2003). An empty shell accumulation provides refuges to other macroinvertebrates from predation (Sousa et al., 2008b). Spooner and Vaughn (2006), using two species of unionid mussels (*Actinonaias ligamentina* and

*Amblema plicata*), showed that the highest invertebrate abundance occurred in treatments with live mussels. The high density of invertebrates, such as oligochaetes and ephemeropterans, is a response to high levels of biodeposited organic matter and excreted nutrients by mussels. In fact, the presence of zebra mussel (*Dreissena polymorpha*) causes increases in total macroinvertebrates biomass, and densities of hydrozoans, flatworms, and amphipods. This species gives refuge structures from predation and organic matter deposition that provide food and habitat for these taxa (Stewart et al., 2003; Beekey et al. 2004). The presence of *C. fluminea* as ecosystem engineers in the benthos has positive effects in density and richness of other taxa. Werner and Rothhaupt (2007) found that densities of *Caenis spp*. (mayfly) and leeches on soft sediments were enhanced by empty *C. fluminea* shells. Also, studies conducted in Minho River indicate that higher density and biomass of oligochaetes, freshwater sponges and amphipods in patches with high clam densities, compared with low density patches (Sousa et al., 2008b). In contrast, Karatayev et al. (2003) found that the presence of live *C. fluminea* had no effects of other benthic invertebrates.

*Corbicula fluminea* and phytoplankton

Algae blooms are a severe problem in freshwater systems around the world. They promote taste and odor changes, fish kills, lowered water clarity and quality. To control this problem, management authorities have employed biomanipulations, using filter feeders such as mussels (Liu et al., 2009; Nalepa and Schloesser, 1993). In North America, the Asian clam was used to increase water clarity in fish ponds (Nalepa and Schloesser, 1993). According to several authors, one of the major impacts of *C. fluminea* in water bodies is the reduction of suspended materials and phytoplankton abundance, promoting water clarification (Boltovskoy et al., 1995; Cohen et al., 1984; McMahon, 2001). The filtration rate for this species is about 24.1 mL g $WTM^{-1}$ $h^{-1}$ (Cohen et al., 1984). This filtration rate was calculated using the wet total mass (WTM) and the shell length of the clams. According to Boltovskoy et al. (1995), *C. fluminea* is not a selective feeder; it can consume algae with spherical diameter up to 50 µm, however, particle size limits filter feeding, for *C. fluminea,* the most efficient filter feeding occurs with a size about 20-25 µm in natural conditions. Filtration rates and digestion efficiencies of *C. fluminea* also depend on temperatures and algal availability (Boltovskoy et al. 1995; Vaughn and Hakenkamp, 2001). Ying et al. (2009) found that *C. fluminea* preferred *Microcystis aeruginosa* cells to green algae cells (*Scenedesmus obliquus)*. The thick cell wall of *S. obliquus* is indigestible for the clams. Still, the filtering rate of *C. fluminea* was inhibited in the presence of *M. aeruginosa* toxic cells. Soon-Jin et al. (2010) suggest that *Corbicula* can reduce the cyanobacterial blooms in eutrophic waters. However, the filtration rates and mortalities in the clams depend on acclimation prior to exposure to the cyanobacteria.

## Studies with benthic macroinvertebrates in reservoirs of the Caribbean region

In the Caribbean region very few studies on benthic macroinvertebrate communities in reservoirs have been conducted. Hruska (1970) described benthic macroinvertebrates in Mosquito River and Cacoyugüín Reservoir in Cuba. Pérez and Fresneda (1976) studied the dynamics, densities and predation of benthic macroinvertebrate communities during the first year of construction of the Ejército Rebelde Reservoir, Cuba. They found that the benthic macrofauna in this reservoir consisted of a few insects (Diptera and Odonata), crustaceans (Amphipoda) and annelids (Hirudinea and Oligochaeta). Since then, there have been no other studies on the benthic macroinvertebrates in reservoirs of the Caribbean region.

# Materials and Methods

Study sites

Guajataca Reservoir (18º23’51”N 66º55’26”W)

Guajataca Reservoir was constructed in 1929 for public drinking water and irrigation. It is located in the northwest part of the Island, between the municipalities of San Sebastián, Isabela and Quebradillas (Figure 1). The main tributaries are Guajataca River, Chiquito River and Margarita Creek. The surface area is 3.42 $km^2$ and has storage capacity of 42.28 x $10^6$ $m^3$ (Soler-López, 2001). Guajataca Reservoir is classified as mesotrophic, with a value of 40-50 in Total Phosphorus Trophic State Index (TP-TSI) (Amador et al., 2008).

La Plata Reservoir (18º20’24”N 66º14’2”W)

La Plata Reservoir was constructed in 1974 as a public drinking water source. This reservoir is located between the municipalities of Toa Baja, Naranjito and Bayamón (Figure 2). The main tributaries for this reservoir are Caña River, Guadiana River and Ortiz Creek. La Plata Reservoir has a surface area of 3.09 $km^2$ and a storage capacity of 35. 46 x $10^6$ $m^3$ (Soler-López, 2001). It is classified as eutrophic, with a 50-60 TP-TSI (Amador et al. 2008).

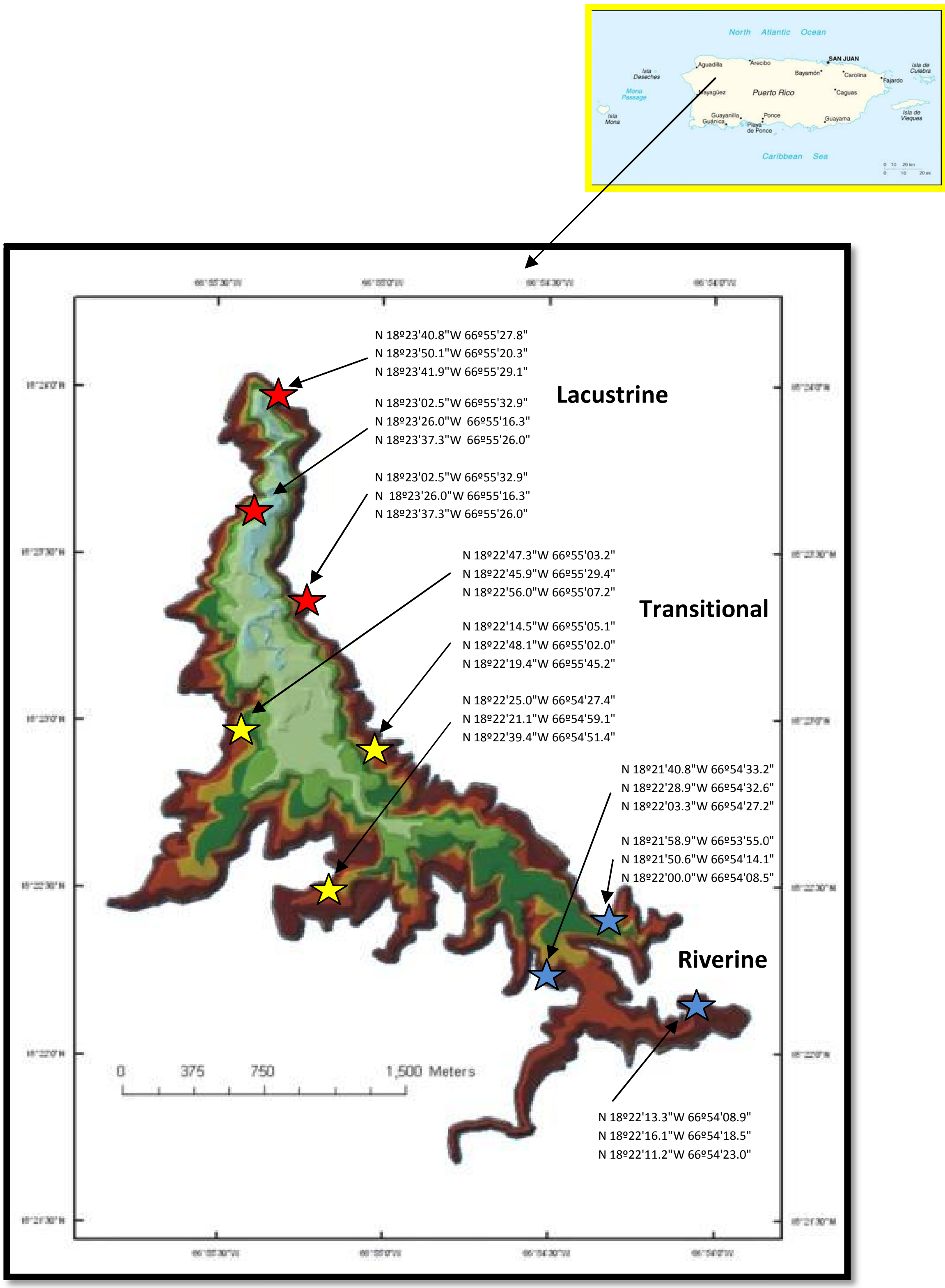



Figure 1. Map of Guajataca Reservoir (USGS) and location of sampling stations.

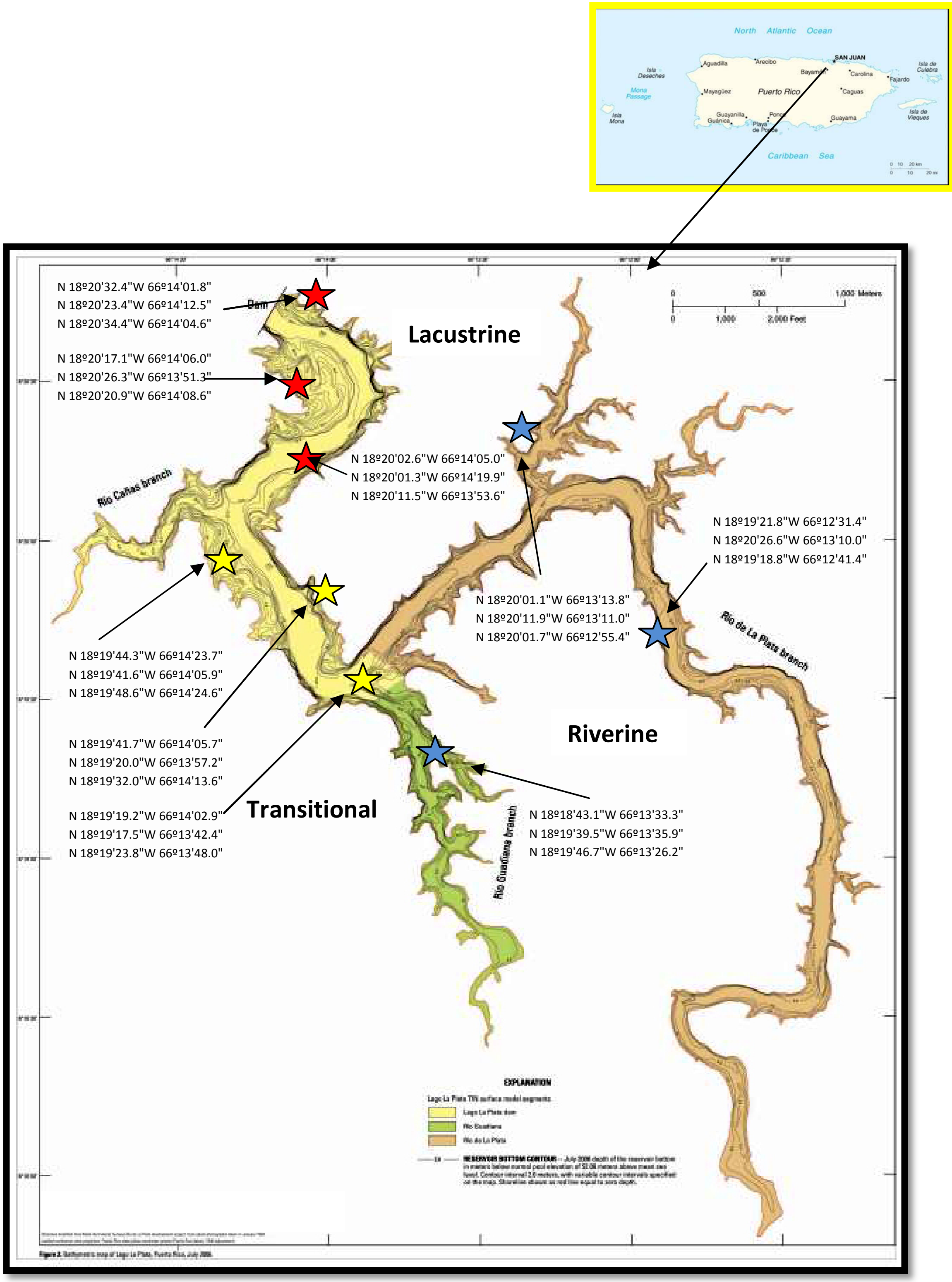



Figure 2. Map of La Plata Reservoir (USGS) and location sampling stations.

## Species description

The Asian clam, *Corbicula fluminea* (Müller), is a freshwater bivalve of the family Corbiculidae (Veneroida: Bivalvia). The periostracum is a yellow-green or light brown color, with concentric grooves, and the shell has anterior and posterior teeth lightly serrate. The nacre can be light blue or violet. Morphotypes exist with olive green or black periostracum and blue nacre. This last morphotype is only known from southwestern United States (Foster et al., 2009). The adult size of the clam can reach 50 to 70 mm (McMahon, 2001).

## Sampling methods

Three sampling trips were undertaken for each reservoir to collect benthic invertebrates, including the Asian clam (*Corbicula fluminea*), and associated sediments. Guajataca Reservoir was visited on 12-15-2010, 1-7-2011, and 2-17-2011, while La Plata Reservoir on 1-29-2011, 2-24-2011, and 3-31-2011. Three areas per reservoir were sampled in triplicate at 0-6 m, with an Ekman grab (225 $cm^2$). Each sample consisted of five grabs (Mackie and Claudi, 2010). The sampling sites were: North-near the dam (lacustrine), Central-middle of the reservoir (transitional), and South-the river area (riverine) of the reservoir. Grab samples were sieved through 0.05 mm mesh and the residue preserved in a solution of 1:4:5, formalin, alcohol, and water, respectively.

Laboratory work

The sieved samples were transported to the laboratory and were weighed and divided in sub-samples depending on the amount of material collected. All samples were analyzed using dissection microscopes. The invertebrates were counted and classified to the lowest taxonomic level possible. The density of invertebrates was calculated using the following formulas:

$$225\ cm^2(5)\left(\frac{1m^2}{10{,}000cm^2}\right) = (0.1125m^2)^{-1} = \frac{8.89}{m^2} = 8.89\ m^{-2}$$

$$(number\ of\ invertebrates\ in\ subsample)(sample\ division)\left(\frac{8.89}{m^2}\right) = \frac{individuals}{m^2}$$

Asian clams (live and empty shells) were counted, measured, and categorized into four size classes. Each size class represented a year class: class I 0-13 mm (0-1 year), class II 13-18 mm (1-2 years), class III 18-24 mm (2-3 years), and class IV 24 mm > (4 or more years) (Cohen et al., 1984).

The identification of benthic macroinvertebrates was performed using dissection microscopes and taxonomic keys such as; Thorp and Covich (2010), Merritt et al. (2008), Perez et al. (2004), Thompson (2004), and Burch (1982). The macroinvetebrates were photographed using the Visionary Digital Integrated Systems photography equipment in the Microscopy Laboratory at the Department of Biology, UPR-M.

Sediment classification

Sediments size percentage compositions were determined in the Sediments Laboratory at the Department of Geology, UPR-M. The samples were processed using the sieve analysis method of Prothero and Schwab (2004). Each sample was dried in an oven at 70 ºC for 48 hours. Samples were weighted and sieved, using -1 Ø for sand and 4 Ø for silt, to determine the grain size percent in the sediments.

Physicochemical parameters

Water analyses such as pH, nutrients and chlorophyll *a* were performed at each station in a concurrent study by Jessica Chappell (graduate student at UPRM). The pH values were measured on site using a YSI Pro Plus multisensor. Water samples were collected from within 1 m of the surface using a 4L Van Dorn bottle, and each sample was divided to evaluate the chlorophyll *a* level, the phytoplankton community assemblage (data not included in this work), and nutrient concentrations. Nutrient concentrations were determined at the Soil and Water Quality Laboratory located at the Río Piedras Agricultural Experimental Station in Río Piedras, Puerto Rico. Nutrients targeted were: total phosphorous (TP) and total kjeldahl nitrogen (TKN). Chlorophyll *a* was determined using the fluorescence protocol originated by the U.S. Environmental Protection Agency (Arar and Collins, 1997).

Temperature and dissolved oxygen concentration were measured *in situ*, while collecting sediments at 0-6 m from the surface, using an electronic multimeter (YSI-85) and water transparency was determined using a Secchi disk. The reservoirs' water levels were determined using the data recorded by U. S. Geological Survey for each sampling date.

Data Analysis

Analysis of the benthic community included species diversity, evenness, richness, and similarity. The analysis of variances (ANOVA) were performed to determine significant differences in densities among sampling stations and sampling dates. Also, ANOVA was used to determine significant differences in physiochemical parameters among stations and dates. Data were transformed to $\log_{10}$ to attain normality. The ANOVA and Tukey-Kramer tests were computed using PH Stat 2 (version 2.7) for Microsoft Excel 2007. Correlations were conducted to determine relations of densities with sediment composition and physiochemical parameters. The hypothesis for this study was that the highest densities of *C. fluminea* are positively related with sandy bottoms and high dissolved oxygen concentrations in both reservoirs.

Species diversity was determined using Shannon and Weaver Index:

$$H' = -\Sigma\left(\frac{n_i}{N}\right) log_{10}\left(\frac{n_i}{N}\right)$$

H': diversity index

$n_i$: number of individuals in the i $^{th}$ species

N: total number of individuals collected

Evenness was determined with following Pielou's (1975) formula:

$$e = \frac{\bar{h}}{\bar{h}_{max}}$$

e: evenness value

$\bar{h}$: $\bar{d}$ (diversity index)

$\bar{h}_{max}$: $\log_2$ S

S: number of species in sample

Community richness was calculated using Margalef's (1957) formula:

$$R = \frac{S-1}{log_e N}$$

R: richness value

S: number of species in sample

N: total number of individuals in sample

The community similarity was calculated using Jaccard's index outlined in Klemm et al., 1990.

$$S_j = \frac{a}{a+b-c}$$

Sj: Jaccard's index

a: numbers of species in reservoir A

b: numbers of species in reservoir B

c: numbers of species in both reservoirs

# Results

## Community Analysis

Benthic invertebrates

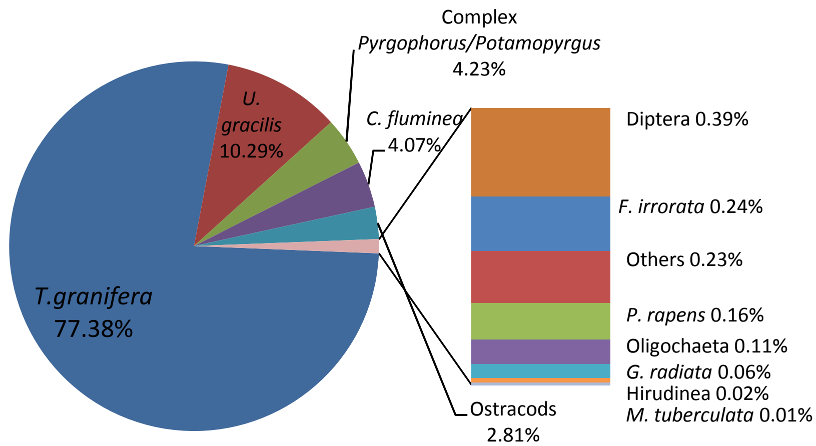
In Guajataca Reservoir samples a total of 91,786 organisms representing 8 phyla, 9 classes, 9 orders, 12 families, and 19 species were found. The check-list of the taxa collected and the stations at which each taxon occurred are shown in Table 1. The highest numerical abundance for this reservoir was the gastropod species *Tarebia granifera* that accounted for 77.38% of the benthic community. It was followed by the entoproct *Urnatella gracilis* (10.29%), the gastropod complex *Pyrgophorus/Potamopyrgus* (4.23%), the bivalve *Corbicula fluminea* (4.07%), and ostracods (2.81%); the other groups of invertebrates only account for 1.22% of the benthic community in Guajataca Reservoir (Figure 3).

The estimated mean total density for this reservoir is 61,042 organisms/$m^2$ (± 3.0). The estimated mean densities for the major macroinvertebrate groups in this reservoir were: *T. granifera* [43,021 individuals/$m^2$ (± 3.4)], *U. gracilis* [5,097 individuals/$m^2$ (± 4.9)], complex *Pyrgophorus/Potamopyrgus* [1,961 individuals/$m^2$ (± 4.3)], and *C. fluminea* [1,754 individuals/$m^2$ (± 4.1)]. The density estimate of the benthic macroinvertebrates for Guajataca Reservoir at the temporal level had the lowest mean total density during January 2011, with value of 37,095 organisms/$m^2$ (± 3.5). The highest mean total density was seen in February 2011, with 95,300 organisms/$m^2$ (± 2.2) (Table 3). One way ANOVA tests showed no significant differences ($p\text{-value} = 0.19, F = 1.79$) in the densities of the benthic community at the temporal level for Guajataca Reservoir (Appendix CA 1).

On the spatial level (stations), benthic macroinvertebrates (Table 3) had the lowest mean total density in the *lacustrine* station with 25,540 organisms/$m^2$ (± 3.5). The highest mean total density for the stations was observed in the *transitional* station with a value of 140,780 organisms/$m^2$ (± 1.8) (Figure 5). One way ANOVA tests showed significant differences (*p-value = 0.001, F= 8.72*) among the mean densities of the benthic invertebrates between the sampling stations in Guajataca Reservoir, (Appendix CA2). More specifically, Tukey-Kramer Multiple Comparisons showed that there are differences between the means of lacustrine and transitional stations (Appendix CA3).

Combining the temporal and spatial components, the estimated mean total densities for sampling stations are reported on Table 4. The lowest mean value for lacustrine [9,305 organisms/$m^2$ ± (2.34)] and transitional [103,896 organisms/$m^2$ ± (2.19)] stations were recorded in January 2011. The lowest mean total density estimate for the *riverine* station was recorded during December 2010, with 38,455 organisms/$m^2$ ± (1.54). The highest mean total density estimate for the lacustrine [46,856 organisms/$m^2$ ± (3.26)] and riverine [124,666 organisms/$m^2$ ± (1.19)] station were detected in February 2011. The highest total mean value for the transitional station was recorded in December 2010, with 181,242 organisms/$m^2$ ± (2.09). The ANOVA test showed no significant differences in the benthic invertebrates densities among sampling dates for the lacustrine (*p-value = 0.25, F= 1.77*) and transitional (*p-value = 0.58, F = 0.59*) stations (Appendix CA4 and CA5). However, significant differences were detected in the benthic invertebrates densities among sampling dates for the riverine station (*p-value = 0.004, F = 15.3*) (see Appendix CA6). Tukey-Kramer Multiple Comparisons showed differences between means on sampling dates for December and February and between January and February in Guajataca Reservoir (Appendix CA7).

**Figure 3. Relative abundance of the major groups of benthic macroinvertebrates collected in Guajataca Reservoir.**




In La Plata Reservoir, a total of 80,979 organisms were counted. These organisms represented 8 phyla, 10 classes, 11 orders, 12 families, and 17 species. The check-list of the taxa collected and the stations at which each occurred are shown in Table 2. The highest numerical abundance for La Plata Reservoir belonged to the gastropod *Tarebia granifera* that composed 50.37% of the benthic macroinvertebrates. It was followed by the entoproct *Urnatella gracilis* (34.81%), ostracods (5.98%), the bivalve *Corbicula fluminea* (3.35%), members of the insect order Diptera (2.08%), and the gastropod complex *Pyrgophorus/Potamopyrgus* (1.62%). The other minor groups of invertebrates, such as Oligochaeta, *Plumatella repens*, *Ferrissia irrorata*, *Melanoides tuberculata*, Hirudinea, and others; just comprised 1.80% of the benthic invertebrates community in the shallow sampled areas of La Plata Reservoir (Figure 4).

The estimated total mean density of the benthic invertebrates for La Plata Reservoir is 37,485 organisms/m$^2$ ± (2.41). The estimated mean densities for the major macroinvertebrates groups in this reservoir were: *C. fluminea* [194 organisms/m$^2$ ± (13.1)], *T. granifera* [11,590 organisms/$m^2$ ± (4.47)], complex *Pyrgophorus/Potamopyrgus* [349 organisms/$m^2$ ± (3.98)], *U. gracilis* [4,248 organisms/$m^2$ ± (19.42)], ostracoda [464 organisms/$m^2$ ± (13.62)] and Diptera [210 organisms/$m^2$ ± (18.23)]. At a temporal scale, the lowest total mean density values was recorded during February 2011, with 30,172 organisms/$m^2$ ± (3.03) and the highest total mean density was recorded in March 2011, with mean value of 42,578 organisms/$m^2$ ± (2.17) (Table 3). However, the ANOVA test did not show significant differences (*p-value = 0.68, F = 0.40*) in the density of the benthic invertebrates among sampling dates for La Plata Reservoir (Appendix CA8).

The estimated means of the total benthic invertebrates' densities for La Plata Reservoir by sampling stations are reported on Table 3. The lowest mean density was obtained at the riverine station with 20,874 organisms/$m^2$ ± (3.37). The highest mean total density was seen at the transitional station with 60,162 organisms/$m^2$ ± (1.69) (Figure 6). The ANOVA test showed significant differences exist (*p-value = 0.03, F = 4.20*) in the densities of the benthic invertebrates in La Plata Reservoir at a spatial level (Appendix CA9). The Tukey-Kramer Multiple Comparisons Test showed differences between the means of the transitional and riverine stations (Appendix CA10).

The estimated mean total densities for the sampling stations by time at La Plata Reservoir are reported on Table 4. The lowest mean total densities estimates for the lacustrine [39,243 organisms/$m^2$ ± (1.51)], transitional [40,912 organisms/$m^2$ ± (1.90)], and Riverine [17,109 organisms/$m^2$ ± (6.67)] stations were recorded during February 2011 (Figure 6). The highest mean total density estimates for the lacustrine [44,336 organisms/$m^2$ ± (1.56)] and transitional [77,185 organisms/$m^2$ ± (1.33)] stations were achieved in March 2011. The highest mean total density for riverine station was 23,570 organisms/$m^2$ ± (3.06) in January 2011. The ANOVA tests showed no significant differences in the benthic invertebrates' densities among sampling dates for the lacustrine (*p-value = 0.92, F= 0.08*), transitional (*p-value = 0.32, F = 1.36*), and riverine (*p-value = 0.95, F = 0.04*) (Appendices CA11, CA12, and CA13).

**Figure 4. Relative numerical abundance of major benthic macroinvertebrates collected in La Plata Reservoir.**

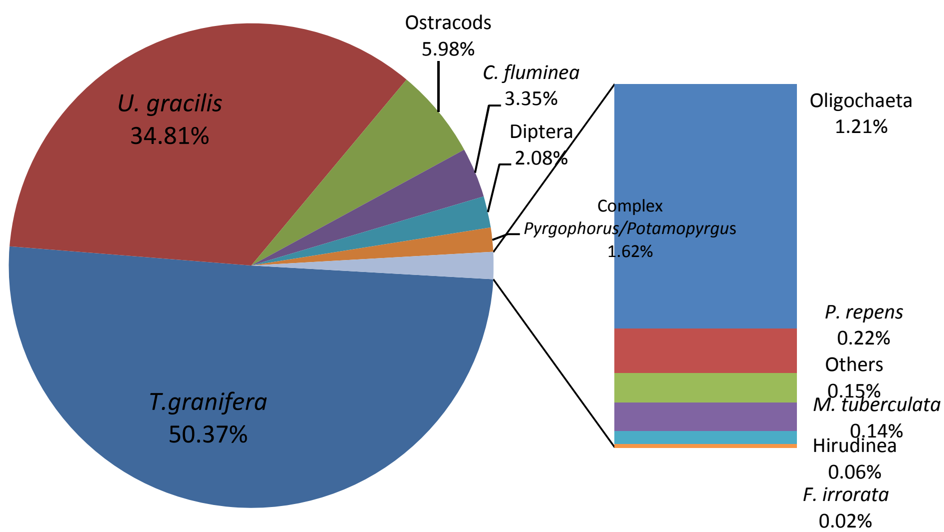


Table 1. Taxonomic summary of the benthic macroinvertebrates collected in Guajataca reservoir during the study and the station in which taxa were collected.

| Taxonomy | | | | | | | Station | | |
|---|---|---|---|---|---|---|---|---|---|
| Phylum | Class | Subclass | Order | Family | Genus | Species | Lacustrine | Transitional | Riverine |
| Mollusca | Bivalvia | Heterodonta | Veneroida | Corbiculidae | *Corbicula* | *C. fluminea* | x | x | x |
| | | | | Pisidiidae | *Pisidium* | *P. casertanum* | x | x | |
| | | | | | *Eupera* | *E. portoricensis cf.* | | | x |
| | Gastropoda | | Neotaenioglossa | Thiaridae | *Tarebia* | *T. granifera* | x | x | x |
| | | | | | *Melanoides* | *M. tuberculata* | x | x | |
| | | | | Hydrobiidae | *Pyrgophorus* | *P. coronatus* | x | x | x |
| | | | | | | *P. parvulus* | x | x | x |
| | | | | | *Potamopyrgus* | *P. antipodarum* | x | x | x |
| | | | Basommatophora | Physidae | *Physa* | *P. marmorata* | x | x | |
| | | | | | | *P. cubensis* | x | x | x |
| | | | | Planorbidae | *Menetus* | *M. dilatatus* | | | x |
| | | | | Ancylidae | *Gundlachia* | *G. radiata* | x | x | x |
| | | | | | *Ferrissia* | *F. irrorata* | x | x | x |
| | | Prosobranchia | Architaenioglossa | Ampullaridae | *Pomacea* | *P. cumingi* | x | x | x |
| | | | | | *Marisa* | *M. cornuaretis* | x | x | x |
| Ectoprocta | Phylactolaemata | | Plumatellida | Plumatellidae | *Plumatella* | *P. repens* | x | x | x |
| Entoprocta | | | | Barentsiidae | *Urnatella* | *U. gracilis* | x | x | x |
| Annelida | Clitellata | Oligochaeta | | | ? | ? | x | x | x |
| | Hirudinea | | | | ? | ? | x | x | x |
| Platyhelminthes | Turbellaria | | | | ? | ? | x | x | x |
| Nematoda | | | | | ? | ? | x | x | |
| Cnidaria | Hydrozoa | Hydroidolina | Anthoathecatae | Hydridae | *Chlorohydra* | *C. viridissima* | x | | x |
| Arthropoda | Insecta | Pterygota | Diptera* | Chironomidae* | ? | ? | x | x | x |
| | | | Coleoptera | | ? | ? | x | | |
| | | | Hemiptera | | ? | ? | x | x | |
| | Ostracoda | | | | ? | ? | x | x | x |
| | Branchiopoda | | Diplostraca | Daphniidae | *Simocephalus* | ? | x | | x |
| | | | | Chydoridae | *Kurzia* | *K. polyspina* | x | | |
| | | | | | *Leydigiopsis* | ? | x | | |

Table 2. Taxonomic summary of the benthic macroinvertebrates collected in La Plata reservoir during the study and the station in which taxa were collected.

| Taxonomy | | | | | | | Station | | |
|---|---|---|---|---|---|---|---|---|---|
| Phylum | Class | Subclass | Order | Family | Genus | Species | Lacustrine | Transitional | Riverine |
| Mollusca | Bivalvia | Heterodonta | Veneroida | Corbiculidae | *Corbicula* | *C. fluminea* | x | x | x |
| | | | | Pisidiidade | *Pisidium* | *P.casertanum* | x | | x |
| | Gastropoda | | Neotaenioglossa | Thiaridae | *Aylacostoma* | *A. pulcher cf.* | x | | |
| | | | | | *Tarebia* | *T. granifera* | x | x | x |
| | | | | | *Melanoides* | *M. tuberculata* | x | x | x |
| | | | | Hydrobiidae | *Pyrgophorus* | *P. coronatus* | x | x | x |
| | | | | | | *P. parvulus* | x | x | x |
| | | | | | *Potamopyrgus* | *P. antipodarum* | x | x | x |
| | | | | Pleuroceridae | *Elimia cf.* | ? | | | x |
| | | | Basommatophora | Physidae | *Physa* | *P. marmorara* | x | | x |
| | | | | Ancylidae | *Gundlachia* | *G. radiata* | x | | |
| | | | | | *Ferrissia* | *F. irrorata* | x | x | x |
| | | Prosobranchia | Architaenioglossa | Ampullaridae | *Pomacea* | *P. cumingi* | | | x |
| | | | | | *Marisa* | *M. cornuaretis* | | x | |
| Ectoprocta | Phylactolaemata | | Plumatellida | Plumatellidae | *Plumatella* | *P. repens* | x | x | x |
| Entoprocta | | | | Barentsiidae | *Urnatella* | *U. gracilis* | x | x | x |
| Annelida | Clitellata | Oligochaeta | | ? | ? | ? | x | x | x |
| | Hirudinea | | | ? | ? | ? | x | x | x |
| Platyhelminthes | Turbellaria | | | ? | ? | ? | x | x | x |
| Nematoda | | | | ? | ? | ? | x | x | x |
| Cnidaria | Hydrozoa | Hydroidolina | Anthoathecatae | Hydridae | *Hydra* | *H. vulgaris* | | | x |
| Arthropoda | Insecta | Pterygota | Diptera* | ? | ? | ? | x | x | x |
| | | | | Chironomidae* | ? | ? | x | x | x |
| | | | Coleoptera | ? | ? | ? | | | x |
| | | | Ephemeroptera | ? | ? | ? | | | x |
| | | | Hemiptera | ? | ? | ? | | | x |
| | Ostracoda | | | ? | ? | ? | x | x | x |
| | Branchiopoda | | Diplostraca | Ilyocryptidae | *Ilyocryptus* | ? | | | x |
| | Malacostraca | Eumalacostraca | Amphipoda | ? | *Hyalella* | *H. azteca* | | x | x |

Figure 5. Estimated mean abundance of benthic invertebrates for Guajataca Reservoir in sampling stations combined (A) and individually: Lacustrine (B), Transitional (C), and Riverine (D).

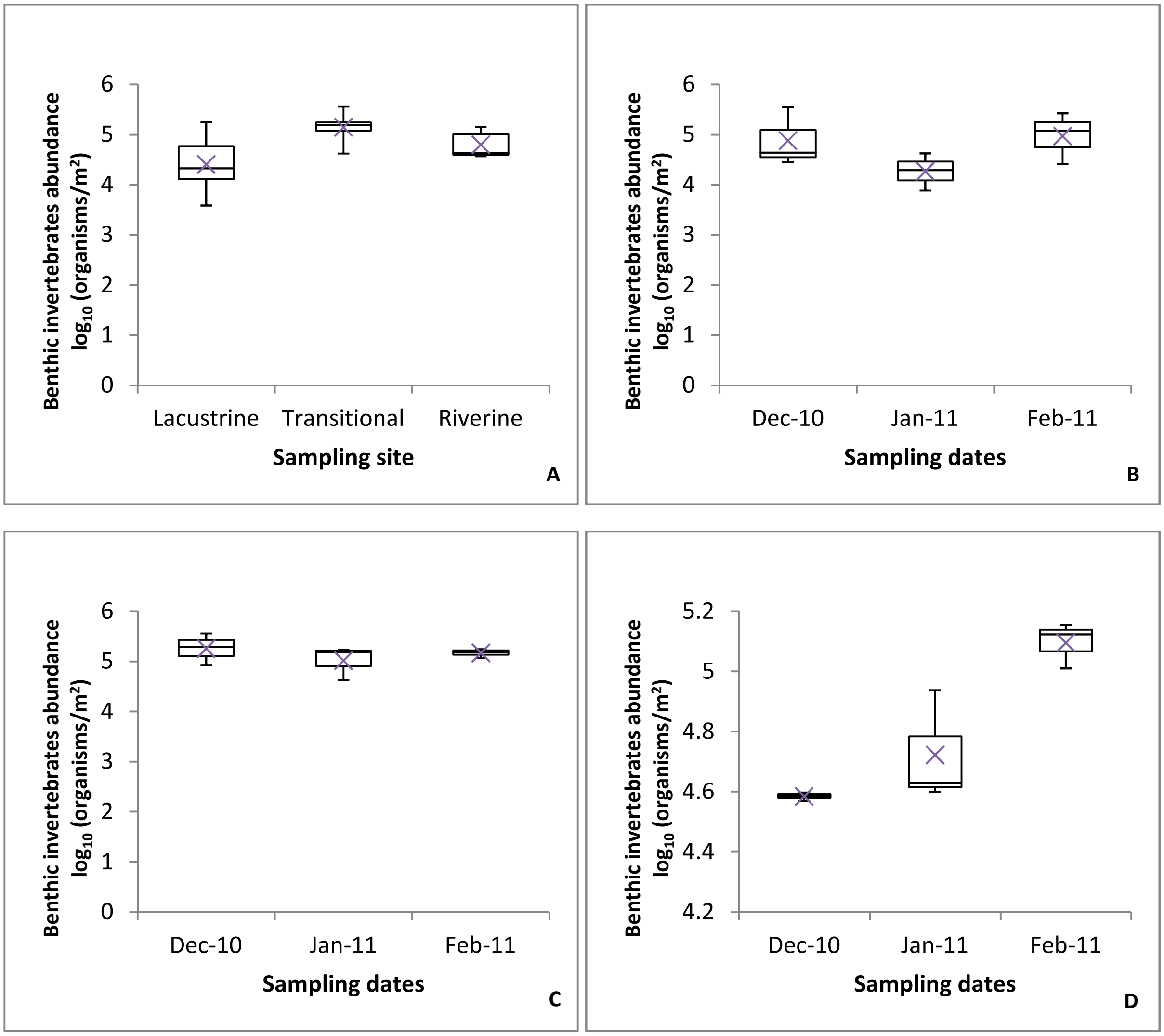


Figure 6. Estimated densities of the benthic invertebrates in La Plata Reservoir (A) sampling localities, (B) Lacustrine, (C) Transitional, and (D) Riverine.

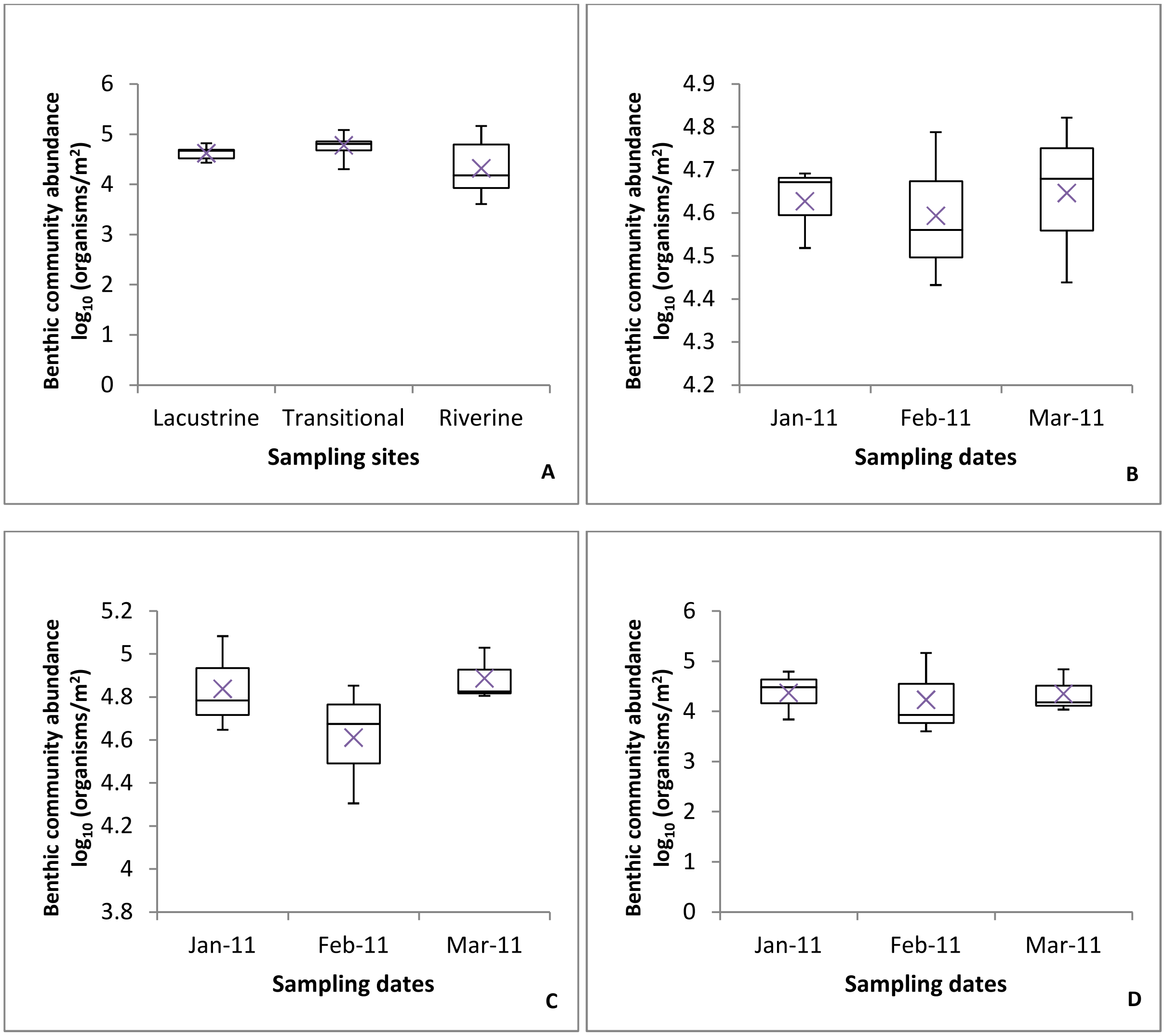


Table 3. Estimated mean total densities (organisms/$m^2$) of benthic organisms from Guajataca and La Plata Reservoirs at temporal and spatial scales.

| Reservoir | | Time: December 2010 | Time: January 2011 | Time: February 2011 | Time: March 2011 | Stations: Lacustrine | Stations: Transitional | Stations: Riverine |
|---|---|---|---|---|---|---|---|---|
| ***Guajataca*** | ***mean*** | 64,338 | 37,096 | 95,300 | *n/a* | 25,540 | 140,780 | 63,258 |
| | ***sd*** | 3 | 3.5 | 2.2 | *n/a* | 3.5 | 1.8 | 1.8 |
| | ***Upper limit*** | 17,914 | 11,954 | 19,034 | *n/a* | 8,297 | 20,333 | 8,751 |
| | ***Lower limit*** | 14,012 | 9,041 | 15,865 | *n/a* | 6,262 | 17,767 | 7,687 |
| ***La Plata*** | ***mean*** | *n/a* | 41,000 | 30,172 | 42,578 | 41,942 | 60,162 | 20,874 |
| | ***sd*** | *n/a* | 2.18 | 3.03 | 2.17 | 1.39 | 1.69 | 3.37 |
| | ***Upper limit*** | *n/a* | 7,849 | 8,538 | 8,089 | 3,207 | 7,541 | 6,564 |
| | ***Lower limit*** | *n/a* | 6,588 | 6,655 | 6,797 | 2,980 | 6,701 | 4,994 |

Table 4. Estimated mean total densities (organisms/$m^2$) of benthic macroinvertebrates for stations by time in Guajataca and La Plata Reservoirs.

| | | **Sampling dates** | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **December 2010** | | | | **January 2011** | | | | **February 2011** | | | | **March 2011** | | | |
| *Reservoir* | | *mean* | *sd* | *Upper* | *Lower* | *mean* | *sd* | *Upper* | *Lower* | *mean* | *sd* | *Upper* | *Lower* | *mean* | *Sd* | *Upper* | *Lower* |
| ***Guajataca*** | ***Lacustrine*** | 38,211 | 3.8 | 26,345 | 15,594 | 9,305 | 2.3 | 3,661 | 2,627 | 46,856 | 3.3 | 27,386 | 17,284 | n/a | n/a | n/a | n/a |
| | ***Transitional*** | 181,242 | 2.1 | 60,477 | 45,346 | 103,896 | 2.2 | 37,115 | 27,346 | 148,171 | 1.2 | 12,027 | 11,124 | n/a | n/a | n/a | n/a |
| | ***Riverine*** | 38,455 | 1 | 474 | 468 | 52,802 | 1.5 | 9,661 | 8,167 | 124,666 | 1.2 | 8,746 | 8,172 | n/a | n/a | n/a | n/a |
| ***La Plata*** | ***Lacustrine*** | n/a | n/a | n/a | n/a | 42,405 | 1.2 | 3,752 | 3,447 | 39,243 | 1.5 | 6,876 | 5,851 | 44,336 | 1.6 | 8,410 | 7,069 |
| | ***Transitional*** | n/a | n/a | n/a | n/a | 68,958 | 1.7 | 15,277 | 12,506 | 40,912 | 1.9 | 11,650 | 9,068 | 77,185 | 1.3 | 9,064 | 8,111 |
| | ***Riverine*** | n/a | n/a | n/a | n/a | 23,570 | 3.1 | 12,856 | 8,319 | 17,109 | 6.7 | 18,714 | 8,938 | 22,556 | 2.7 | 10,576 | 7,200 |

Asian clam (*Corbicula fluminea*) and other bivalves

In Guajataca Reservoir a total of 3,572 bivalves were counted during this study including, 3,500 *Corbicula fluminea*, 71 *Pisidium casertanum*, and only one *Eupera cf. portoricensis*. The Asian clam, was collected at all of the sampling stations; the pea clam, *Pisidium casertanum,* was collected at the lacustrine and transitional stations, and *Eupera cf. portoricensis* was found only in the riverine station (Table 1).

The Asian clam accounted for only 4.07% of the total number of benthic invertebrates (Figure 3). Of all collected clams, 96.1% belonged to Class I size (0-13 mm), (Figure 7), 42.1% were empty shells, while the rest (57.9%) were alive when sampled. The estimated mean density of *C. fluminea* in this reservoir was 1,754 individuals/$m^2$ (±4.1). The mean densities for this species by time and locality are reported on Table 5 and Table 6, respectively. The temporal distribution of *C. fluminea* had the lowest mean density value during December 2010, with 1,000 individuals/$m^2$ (±4.7). And the highest mean value was recorded during February 2011, with 4,539 individuals/$m^2$ (±2.6) (Figure 8). The lowest mean value was obtained in the lacustrine station, with 1,051 individuals/$m^2$ (±4.0). The highest mean value was recorded in the transitional station, with 3,313 individuals/$m^2$ (±4.3) (Figure 9). The ANOVA test showed significant differences on the temporal distribution (*p-value* $= 0.04, F = 3.8$), but not on a spatial basis (*p-value* $= 0.21, F = 1.64$) (Appendices CA14 and CA15). Tukey-Kramer Multiple Comparisons showed differences between the means for December and February 2011 (Appendix CA16).

The estimated mean densities for *C. fluminea* by size class in Guajataca Reservoir were: class I- 1,596 individuals/m$^2$ (± 4.0), class II- 1 individual/m$^2$ (± 7.3), class III- 4 individuals/m$^2$ (± 14.5), and class IV- 7 individuals/m$^2$ (± 16.1). The estimated mean densities for *C. fluminea* along sampling dates are reported on Table 7. The December 2010 sampling had the lowest estimated mean density for class I, with 915 individuals/m$^2$ (± 4.8). The January 2011 sampling had the lowest estimated mean densities for class II with 0 individuals/m$^2$ (±1) and class IV with 5 individuals/m$^2$ (±19.4), and the highest mean density for class III with 4 individuals/m$^2$ (±24.0). The February 2011 sampling had the lowest estimated mean density for class III with 3 individuals/m$^2$ (±15.7) and the highest estimated density for class I with 3,991 individuals/m$^2$ (±2.8), class II with 4 individuals/m$^2$ (±11.7), and class IV with 10 individuals/m$^2$ (±23.9). The ANOVA tests suggested no significant differences in the densities of class I (*p-value = 0.05, F = 3.48*), class II (*p-value = 0.91, F = 0.09*), class III (*p-value = 0.20, F = 1.71*), and class IV (*p-value = 0.94, F = 0.05*) by sampling dates (Appendices CA17, CA18, CA19, and CA20, respectively).

The estimated mean densities of *C. fluminea* along stations in Guajataca Reservoir are reported on Table 8. The lacustrine station had the lowest estimated mean densities for class I [1,032 individuals/m$^2$ (±3.9], class II [1 individual/m$^2$ (±4.7)], class III [1 individuals/m$^2$ (±6.9)], and class IV [5 individuals/m$^2$ (±12.6)]. The transitional station had the highest mean densities for class I [3,035 individuals/m$^2$ (±4.4)], class III [12 individuals/m$^2$ (±21.9)], and class IV [8 individuals/m$^2$ (±14.7)]. The ANOVA test showed no significant differences in the densities of class I (*p-value = 0.24, F = 1.54*), class II (*p-value = 0.91, F = 0.09*), class III (*p-value = 0.20, F =1.71*), and class IV (*p-value = 0.94, F =0.05*) among stations (Appendices CA21, CA22, CA23, and CA24, respectively).

In La Plata Reservoir, a total of 1,344 bivalves were counted during the study; 1,339 were *C. fluminea* and 5 were *P. casertanum*. Only one *E. cf. portoricensis* was collected during the pre-sampling in August 2010, which was not part of the statistical and community analysis. In this reservoir, the Asian clam was collected in all sampling stations, and *P. casertanum* was collected in the lacustrine and riverine stations (Table 2).

In La Plata Reservoir, the relative abundance of *C. fluminea* was about 3.34% of the total benthic invertebrates counted (Figure 4). Of the collected clams, 96.7% belonged to size class I (0-13 mm) (Figures 7), 37.2% were empty shells, and 62.8% were alive. The estimated mean density of *C. fluminea* was 204 individuals/$m^2$ (±11.6). The temporal and spatial mean densities for this species in La Plata are reported on Tables 5 and 6, respectively. The Asian clam had the lowest mean temporal value in February 2011, with 52 individuals/$m^2$ (±17). The highest mean value was in March 2011, with 394 individuals/$m^2$ (±8.0) (Figure 30). The lowest mean spatial value was observed at the lacustrine station [57 individuals/$m^2$ (±7.1)]. The highest mean value was recored in the transitional station [927 individuals/$m^2$ (±4.6)] (Figure 31). The ANOVA test for temporal distribution of *C. fluminea* showed no significant differences (*p-value= 0.17, F= 1.92*) for La Plata Reservoir (Appendix CA25). However, the ANOVA test showed significant differences (*p-value = 0.05, F = 3.37*) in the densities of Asian clams among stations (Appendix CA26a). Indeed, the Tukey-Kramer Multiple Comparisons showed differences between the means of the lacustrine and transitional stations (Appendix CA27).

The estimated mean densities for *C. fluminea* by size class in La Plata Reservoir were: class I- 101 individuals/$m^2$ (± 16.45), class II- 1 individual/$m^2$ (± 3.11), class III- 1 individual/$m^2$ (± 5.21), and class IV- 2 individuals/$m^2$ (± 8.97). The mean densities along sampling dates are reported on Table 7. The February 2011 sampling had the lowest estimated mean density for class I with 46 individuals/$m^2$ (± 21.35) and class II with 0 individuals/ $m^2$ (±1). The January 2011 sampling had the lowest estimated mean densities for class IV with 1 individual/$m^2$ (±5.73). The highest estimated mean densities for class I, class II, and class IV were obtained during March 2011, with 374 individuals/$m^2$ (±7.72), 1 individual/$m^2$ (±4.71), and 3 individuals/$m^2$ (±13.57), respectively. The estimated mean densities for class III were 1 individuals/$m^2$ on the three sampling dates. The ANOVA tests showed no significant differences in the densities of size class I (*p-value = 0.23, F = 1.55)*, class II *(p-value = 0.77, F = 0.27)*, class III *(p-value = 0.35, F = 1.1)*, and class IV *(p-value = 0.77, F = 0.26)* among sampling dates (Appendices CA28, CA29, CA30, and CA31, respectively). The estimated mean densities in stations are reported on Table 8. The transitional station had the lowest estimated mean density for class II [0 individuals/$m^2$ (±1)], and the highest estimated mean densities for class I [202 individuals/$m^2$ (±16.9)] and class IV [3 individuals/$m^2$ (±14.8)]. The riverine station had the lowest mean densities for class I [68 individuals/$m^2$ (±28.8)] and class IV [1 individual/$m^2$ (±5.1)]. The mean densities for class II and class III in the lacustrine and riverine stations were 1 individual/$m^2$. The ANOVA test showed no significant differences in the densities of class I (*p-value = 0.68, F = 0.40*), class II (*p-value = 0.37, F = 1.04*), class III (*p-value = 0.53, F = 0.65*), and class IV (*p-value = 0.66, F= 0.43*) among stations (Appendices CA32, CA33, CA34, and CA35).

Negative correlation were found between Asian clam densities and TP concentrations ($r^2$*= 0.21, p-value = 0.0004*), and also between clam densities and pH values ($r^2$ *= 0.21, p-value = 0.0004*) (Appendices CA36 and CA37). No correlations were found between the sediments types and the abundances of *C.fluminea* at either reservoir.

Table 5. *Corbicula fluminea* mean densities by sampling dates for Guajataca and La Plata Reservoirs (individuals/$m^2$).

| | | Sampling dates | | | |
|---|---|---|---|---|---|
| *Reservoir* | | *December 2010* | *January 2011* | *February 2011* | *March 2011* |
| ***Guajataca*** | ***Mean*** | 1,000 | 1,189 | 4,539 | n/a |
| | ***Sd*** | 4.7 | 3.4 | 2.6 | n/a |
| | ***upper limit*** | 417 | 377 | 1,093 | n/a |
| | ***lower limit*** | 294 | 286 | 882 | n/a |
| ***La Plata*** | ***Mean*** | n/a | 359 | 52 | 394 |
| | ***Sd*** | n/a | 8.6 | 17.2 | 8.0 |
| | ***upper limit*** | n/a | 224 | 52 | 234 |
| | ***lower limit*** | n/a | 138 | 26 | 147 |

Table 6. *Corbicula fluminea* mean densities by stations for Guajataca and La Plata Reservoirs (individuals/$m^2$).

| | | Stations | | |
|---|---|---|---|---|
| *Reservoir* | | *Lacustrine* | *Transitional* | *Riverine* |
| ***Guajataca*** | ***Mean*** | 1,051 | 3,313 | 1,550 |
| | ***Sd*** | 4.0 | 4.3 | 3.5 |
| | ***upper limit*** | 384 | 1,290 | 499 |
| | ***lower limit*** | 281 | 499 | 378 |
| ***La Plata*** | ***Mean*** | 57 | 927 | 160 |
| | ***Sd*** | 7.1 | 4.6 | 19.9 |
| | ***upper limit*** | 32 | 380 | 154 |
| | ***lower limit*** | 20 | 270 | 78 |

Table 7. Estimated mean densities of *C. fluminea* by size class and sampling dates for Guajataca and La Plata Reservoirs (individuals/m$^2$)±SD.

| | | **Sampling dates** | | | |
|---|---|---|---|---|---|
| *Reservoir* | | *Dec-10* | *Jan-11* | *Feb-11* | *Mar-11* |
| ***Guajataca*** | ***Class I*** | 915±4.8 | 1113±3.3 | 3991±2.8 | n/a |
| | ***Class II*** | 1±8.5 | 0±1 | 4±11.7 | n/a |
| | ***Class III*** | 3±10.6 | 4±24.0 | 3±15.7 | n/a |
| | ***Class IV*** | 6±11.4 | 5±19.4 | 10±23.9 | n/a |
| ***La Plata*** | ***Class I*** | n/a | 59±20.2 | 46±21.3 | 374±7.7 |
| | ***Class II*** | n/a | 1±3.3 | 0±1 | 1±4.7 |
| | ***Class III*** | n/a | 1±2.7 | 1±5.8 | 1±8.5 |
| | ***Class IV*** | n/a | 1±5.7 | 2±10.3 | 3±13.6 |

Table 8. Estimated mean densities of *C. fluminea* by size class and stations for Guajataca and La Plata Reservoirs (individuals/m$^2$)±SD

| | | *Stations* | | |
|---|---|---|---|---|
| | | *Lacustrine* | *Transitional* | *Riverine* |
| ***Guajataca*** | ***Class I*** | 1032±3.9 | 3034±4.4 | 1298±3.5 |
| | ***Class II*** | 1±4.7 | 2±9.2 | 2±10.2 |
| | ***Class III*** | 1±6.9 | 12±21.9 | 3±14.5 |
| | ***Class IV*** | 5±12.6 | 8±14.7 | 8±28.7 |
| ***La Plata*** | ***Class I*** | 75±10.1 | 202±17.0 | 68±28.9 |
| | ***Class II*** | 1±3.3 | 0±1 | 1±4.7 |
| | ***Class III*** | 1±3.8 | 2±10.8 | 1±2.7 |
| | ***Class IV*** | 1±9.8 | 3±14.8 | 1±5.1 |

Figure 7. Relative abundance of *C. fluminea* by size classes for (A) Guajataca Reservoir and (B) La Plata Reservoir.

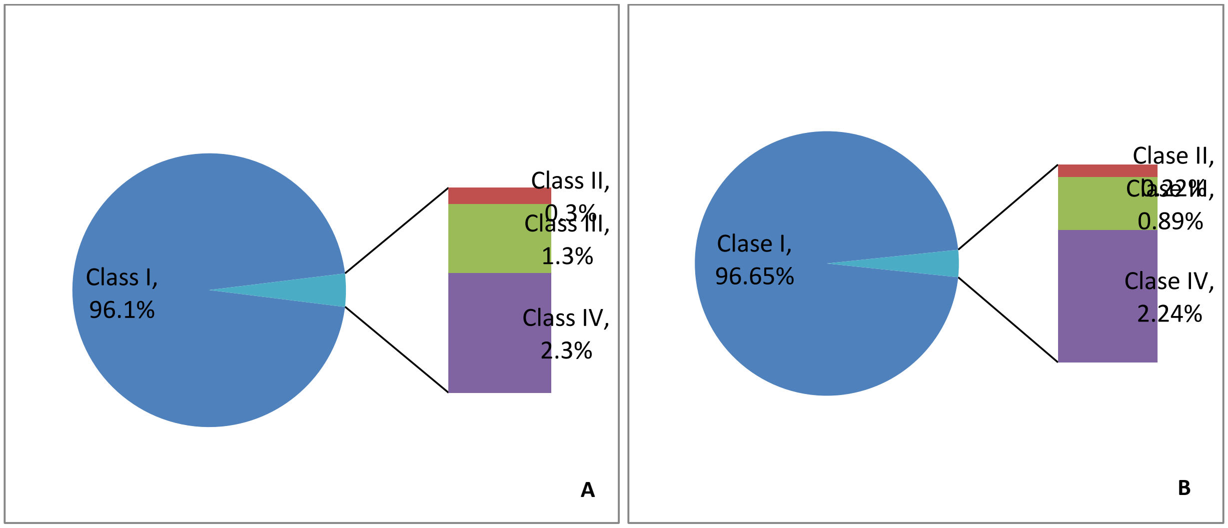



Figure 8. Estimated densities and mean value of *C. fluminea* in sampling dates for (A) Guajataca Reservoir and (B) La Plata Reservoir.

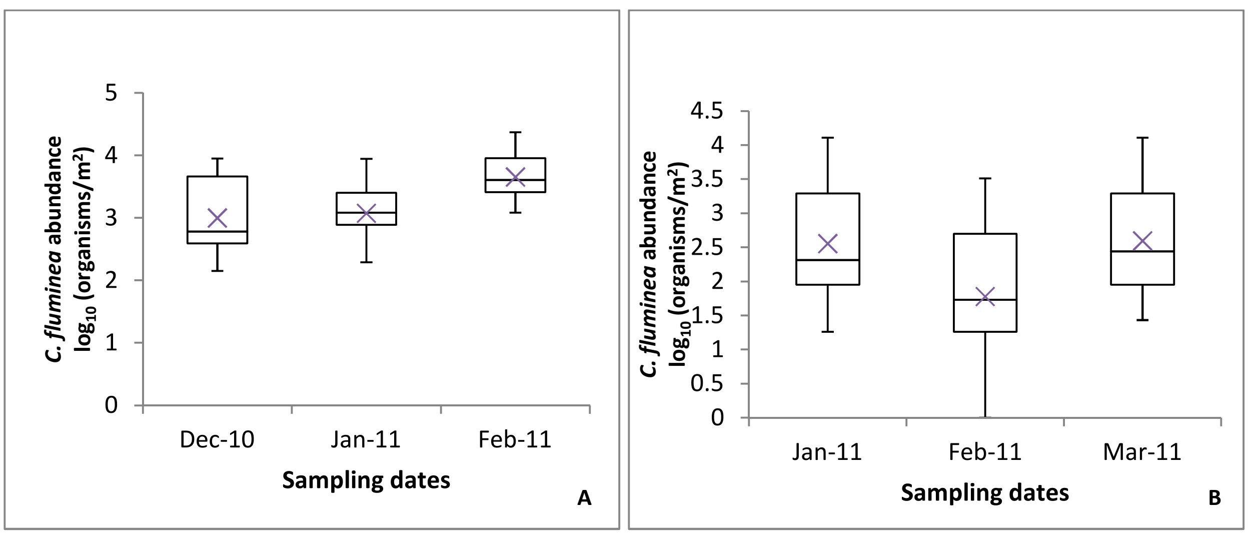
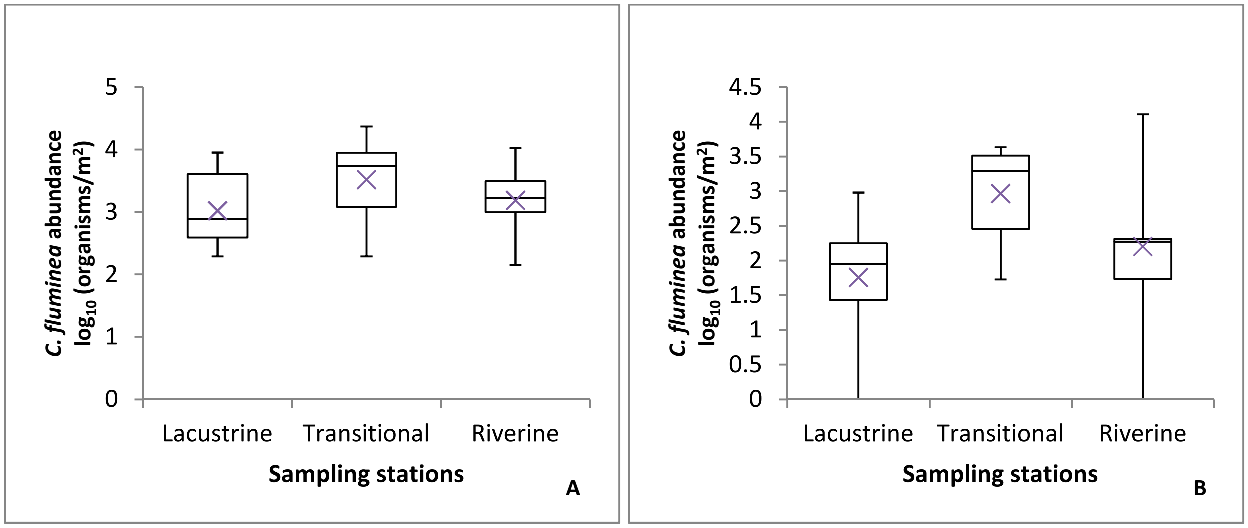


Figure 9. Estimated densities and mean value of *C. fluminea* in stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.




Quilted melania *Tarebia granifera*

During this study, a total of 69,383 *Tarebia granifera* were counted in Guajataca Reservoir. This species is the most abundant organism in the local freshwater benthic invertebrates'communities and had a relative abundance of 77.38% in this reservoir (Figure 3). The estimated mean density of *T. granifera* in Guajataca Reservoir was 43,021 individuals/m$^2$ (±3.4). The mean densities values of *T. granifera* by sampling time and station are reported in Tables 9 and 10, respectively. The temporal distribution of this species had the lowest mean value during January 2011, with 27,974 individuals/m$^2$ (±3.4). The highest mean value was obtained in February 2011, with 64,393 individuals/m$^2$ (±3.1) (Figure 10). The spatial distribution of *T. granifera* in Guajataca Reservoir had the lowest mean value in the lacustrine station [17,389 individuals/m$^2$ (±3.8)] and the highest mean value in the transitional station [113,236 individuals/m$^2$ (±1.9)] (Figure 11). The ANOVA test did not show significant differences (*p-value = 0.36, F = 1.07*) in the temporal distribution of this species for Guajataca Reservoir (Appendix CA38), but did show significant differences (*p-value = 0.002, F = 8.41*) in the spatial distribution of *T. granifera* within this reservoir (Appendix CA39). Tukey-Kramer Multiple Comparisons test showed differences between the means of the lacustrine and transitional stations (Appendix CA40). Negative correlation was found between TP concentrations and *T. granifera* densities ($r^2 = 0.24$, *p-value* $= 0.010$) in this reservoir (see Appendix CA41). Positive correlations were found between *T. granifera* densities and pH levels ($r^2 = 0.38$, *p-value* $= 0.0007$) and DO concentrations ($r^2 = 0.17$, *p-value* $= 0.03$) (Appendices CA42 and CA43).

In La Plata Reservoir's samples, 31,909 *T. granifera* were found. These gastropods comprised 50.38% of the benthic invertebrates counted for La Plata Reservoir (Figure 4). The estimated mean density of *T. granifera* for this reservoir was 11,590 individuals/m$^2$ (±4.5) (Tables 9 and 10, respectively). The temporal distribution of this species had the lowest mean value during February 2011 [4,134 individuals/m$^2$ (±4.2)] and the highest mean value in March 2011 [21,623 individuals/m$^2$ (±3.7)] (Figure 10). The spatial distribution of *T. granifera* in this reservoir had the lowest mean value in the riverine station [4,072 individuals/m$^2$ (±4.1)], and the highest mean value in the transitional station [32,937 individuals/m$^2$ (±2.5)] (Figure 11). The ANOVA test showed significant differences (*p-value* $= 0.03$, $F = 3.99$) in the temporal distribution of *T. granifera* for La Plata Reservoir (Appendix CA44). Tukey-Kramer Multiple Comparisons showed differences in the means of February and March (Appendix CA45). Also, the ANOVA showed differences (*p-value* $= 0.007$, $F = 6.10$) in the spatial distribution of this species (Appendix CA46). Tukey-Kramer Multiple Comparisons tests showed differences in the means of the transitional and riverine stations (Appendix CA47). For this reservoir, negative correlations were found between *T. granifera* densities and TP concentrations ($r^2 = 0.17$, *p-value* $= 0.034$) and TN concentrations ($r^2 = 0.29$, *p-value* $= 0.004$) (Appendices CA48 and CA49).

Positive correlations were reported for *T. granifera* densities with temperatures *($r^2$ = 0.25, p-value = 0.007*) and with secchi depth values (*$r^2$ = 0.18, p-value = 0.026)* (Appendices CA50 and CA51).

Figure 10. Estimated densities *T. granifera* on sampling dates for (A) Guajataca Reservoir and (B) La Plata Reservoir.

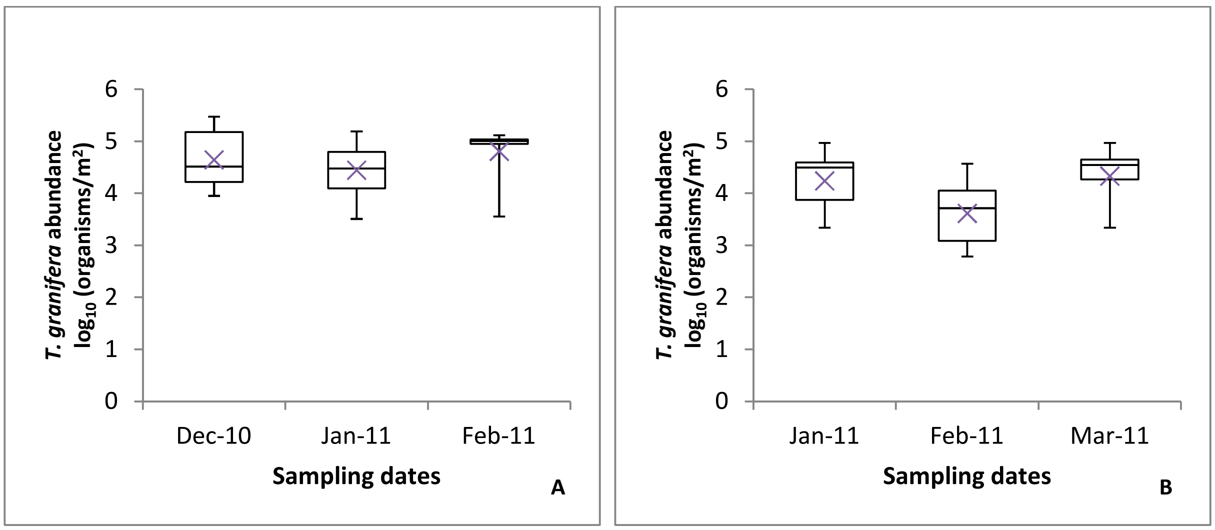



Figure 11. Estimated densities of *T. granifera* in stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.

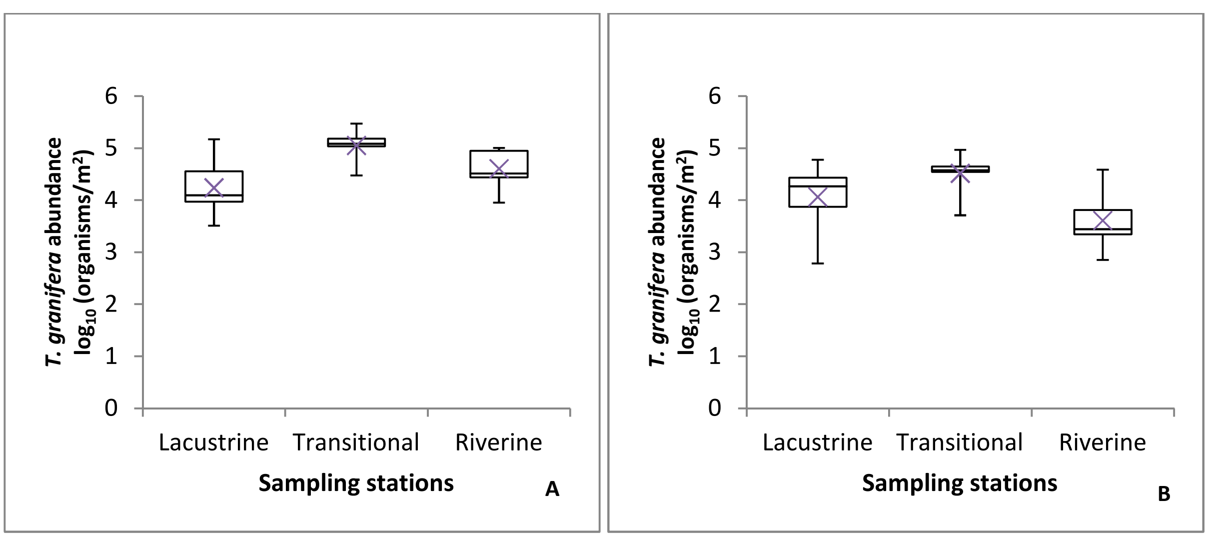


Table 9. *Tarebia granifera* mean densities along sampling dates for Guajataca and La Plata Reservoirs (individuals/m$^2$).

| | | Sampling dates | | | |
|---|---|---|---|---|---|
| *Reservoir* | | *Dec-10* | *Jan-11* | *Feb-11* | *Mar-11* |
| ***Guajataca*** | ***mean*** | 44,205 | 27,974 | 64,393 | n/a |
| | ***sd*** | 3.5 | 3.4 | 3.1 | n/a |
| | ***upper limit*** | 14,567 | 8,853 | 18,930 | n/a |
| | ***lower limit*** | 10,956 | 6,725 | 14,629 | n/a |
| ***La Plata*** | ***mean*** | n/a | 17,414 | 4,134 | 21,623 |
| | ***sd*** | n/a | 3.7 | 4.2 | 3.7 |
| | ***upper limit*** | n/a | 5,930 | 1,568 | 7,439 |
| | ***lower limit*** | n/a | 4,423 | 1,137 | 5,535 |

Table 10. *Tarebia granifera* mean densities by stations for Guajataca and La Plata Reservoirs (individuals/m$^2$).

| | | *Stations* | | |
|---|---|---|---|---|
| *Reservoir* | | *Lacustrine* | *Transitional* | *Riverine* |
| ***Guajataca*** | ***mean*** | 17,389 | 113,236 | 40,439 |
| | ***sd*** | 3.8 | 1.9 | 2.2 |
| | ***upper limit*** | 6,111 | 16,897 | 8,028 |
| | ***lower limit*** | 4,522 | 14,703 | 6,699 |
| ***La Plata*** | ***mean*** | 11,608 | 32,937 | 4,072 |
| | ***sd*** | 4.1 | 2.5 | 4.1 |
| | ***upper limit*** | 4,301 | 7,708 | 1,522 |
| | ***lower limit*** | 3,138 | 6,246 | 1,108 |

Table 11. Complex *Pyrgophorus/Potamopyrgus* mean densities on sampling dates for Guajataca and La Plata Reservoirs (individuals/m$^2$).

| | | Sampling dates | | | |
|---|---|---|---|---|---|
| *Reservoir* | | *Dec-10* | *Jan-11* | *Feb-11* | *Mar-11* |
| ***Guajataca*** | ***mean*** | 2,587 | 1,294 | 2,254 | n/a |
| | ***sd*** | 4.4 | 5.3 | 3.5 | n/a |
| | ***upper limit*** | 1,028 | 585 | 739 | n/a |
| | ***lower limit*** | 736 | 403 | 557 | n/a |
| ***La Plata*** | ***mean*** | n/a | 493 | 210 | 410 |
| | ***sd*** | n/a | 3.6 | 4.3 | 4.1 |
| | ***upper limit*** | n/a | 166 | 81 | 152 |
| | ***lower limit*** | n/a | 124 | 59 | 111 |

Table 12. Complex *Pyrgophorus/Potamopyrgus* mean densities for Guajataca Reservoir by sampling stations individuals/m$^2$).

| | | *Stations* | | |
|---|---|---|---|---|
| | | *Lacustrine* | *Transitional* | *Riverine* |
| ***Guajataca*** | ***mean*** | 11,608 | 32,938 | 4,072 |
| | ***sd*** | | | |
| | ***upper limit*** | 4,301 | 7,708 | 1,522 |
| | ***lower limit*** | 3,138 | 6,246 | 1,108 |
| ***La Plata*** | ***mean*** | 158 | 1,041 | 258 |
| | ***sd*** | 3.9 | 2.7 | 3.0 |
| | ***upper limit*** | 57 | 262 | 71 |
| | ***lower limit*** | 42 | 209 | 56 |

*Pyrgophorus/Potamopyrgus* Complex

This complex contains two genera, from the family Hydrobiidae; *Pyrgophorus* and *Potamopyrgus* and is represented by two species groups; one native to the Caribbean, *Pyrgophorus parvulus* and *P. coronatus* and the other an alien species from New Zealand, *Potamopyrgus antipodarum*. All samples of these gastropods were dead when collected and without the animals inside the shells, it was impossible to identify them to species, thus it was necessary to group them.

In Guajataca Reservoir's samples, a total of 3,912 individuals of this group were counted and comprised 4.23% of the relative abundance in the benthic community here (Figure 3). The mean density of this group was 1,961 individuals/$m^2$ (±4.3). The temporal and spatial mean density values for the "Complex" in this reservoir are reported in Tables 11 and 12. The lowest mean density value occurred in January 2011 [1,294 individuals/$m^2$ (±5.3)], while the highest mean value was recorded in December 2010 [2,587 individuals/$m^2$ (±4.4)] (Figure 12). On a spatial basis, the lowest mean value was detected in the riverine station [4,072 individuals/$m^2$ (±4.1)] and the highest mean value was in the transitional station [32,938 individuals/$m^2$ (±275)] (Figure 13). The ANOVA test for temporal distribution showed no differences (*p-value = 0.58, F = 0.55*) for the Complex *Pyrgophorus/Potamopyrgus* in Guajataca Reservoir (Appendix CA52), however the ANOVA did show significant differences (*p-value = 0.002, F = 7.50*) among sampling stations (spatial scale) in this reservoir (Appendix CA53). The Tukey-Kramer test showed differences between the means of the transitional and riverine stations (Appendix CA54). No correlations were found between this snail complex and the sediments and water parameters for this reservoir.

In La Plata Reservoir, a total of 743 individuals of the “Complex” were collected with relative abundance only about 1.62% (Figure 4). The mean density value of the “Complex” was 349 individuals/m$^2$ (±4.0). The mean temporal and spatial density values of this group are reported on Tables 11 and 12, respectively. The lowest mean density was measured in February 2011 [210 individuals/m$^2$ (±4.3)] and the highest mean density in January 2011 [493 individuals/m$^2$ (±3.6)] (Figure 12).  This group also had the lowest mean density value in the lacustrine station [158 individuals/m$^2$ (±3.9)] and the highest mean value was measured in the transitional station [1,041 individuals/m$^2$ (±2.7)] (Figure 13). The ANOVA test for temporal distribution showed no differences (*p-value = 0.39, F = 0.95*) in the Complex’s densities among sampling dates (Appendix CA55), but did among stations (*p-value = 0.006, F = 6.36*) (Appendix CA56). Tukey-Kramer Multiple Comparisons test showed differences in the means of the lacustrine and transitional and between transitional and riverine stations (Appendix CA57). No correlations were detected between the “snail-complex” and the sediments and water parameters for La Plata Reservoir.

Figure 12. Estimated densities of the Complex *Pyrgophorus/Potamopyrgus* on sampling dates for (A) Guajataca Reservoir and (B) La Plata Reservoir.

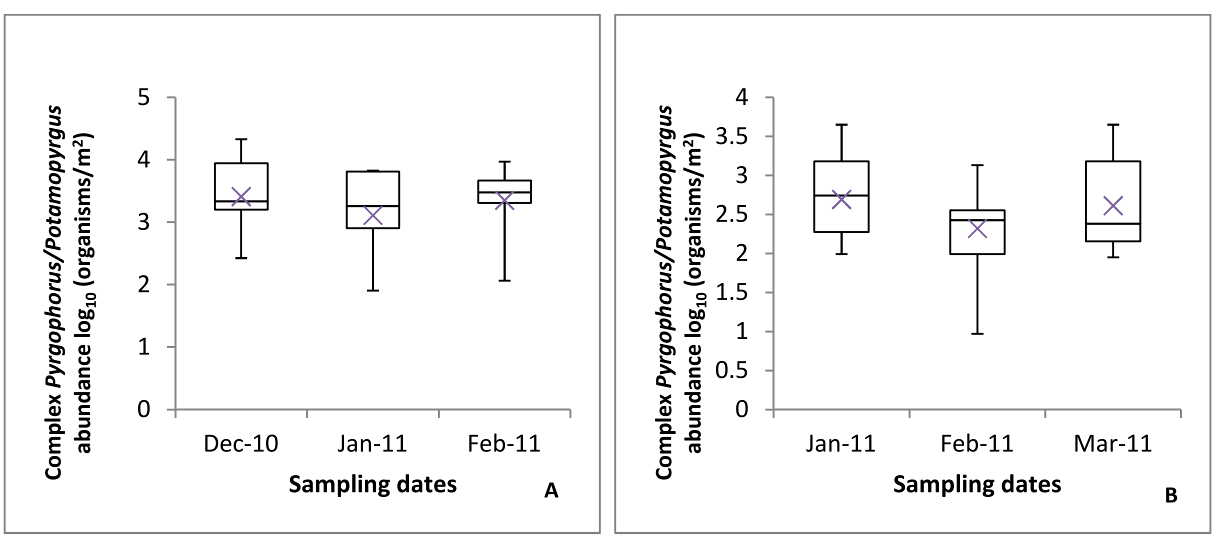
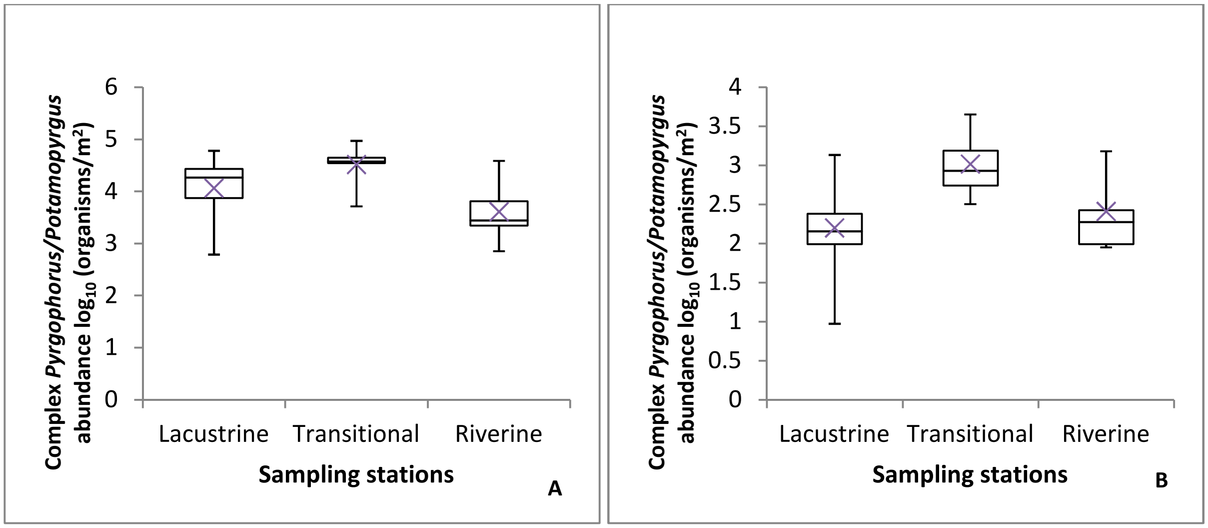


Figure 13. Estimated densities of the Complex *Pyrgophorus/Potamopyrgus* in stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.




Freshwater goblet worm (*Urnatella gracilis*)

This is the first report of the entoproct *Urnatella gracilis* for Puerto Rico, and possibly for the West Indies. It was collected in both reservoirs and found, more often, attached to rocks and wood sticks, but was also seen on snail and clam shells.

In Guajataca, a total of 11,346 *Urnatella* stalks were counted on this study. In this reservoir, its relative abundance was 10.3% of the benthic community (Figure 3). The mean density was 5,097 stalks/m$^2$ (±4.9). The mean densities of *U. gracilis* by time and space are reported on Tables 13 and 14, respectively. This organism had the lowest mean value during January 2011 [2,809 stalks/m$^2$ (±4.1)] and its highest mean value on February 2011 [9,563 stalks/m$^2$ (±9.0)] (Figure 14). It had its lowest mean value in the lacustrine station [1,628 stalks/m$^2$ (±8.3)] and highest mean density in the riverine station [(9,312 stalks/m$^2$ (±2.3)] (Figure 15). The ANOVA test did not show significant differences (*p-value = 0.27, F = 1.38*) in the temporal distribution of *U. gracilis* (Appendix CA58). Instead, significant differences existed (*p-value = 0.02, F = 4.40*) on a spatial basis of this species in Guajataca Reservoir (Appendix CA59). Tukey-Kramer Multiple Comparisons tests showed differences between the means of the lacustrine and riverine stations (Appendix CA60). No correlations were found between the entoproct densities and the water parameters and sediments composition in this reservoir.

A total of 30,423 individuals of *U. gracilis* were collected in the La Plata Reservoir samples during this study for a relative abundance of 34.8% (Figure 4). The mean density of this species was 4,247 stalks/$m^2$ (±16.5). The mean densities for *Urnatella* along sampling times and stations are reported on Tables 13 and 14, respectively. The lowest mean density by time was 2,240 stalks/$m^2$ (±93.6) in February 2011. The highest mean value recorded was 8,177 stalks/$m^2$ (±3.5) during January 2011 (Figure 14). The station with the lowest mean density was the riverine [909 stalks/$m^2$ (±66.0)], while the highest mean density was observed in the lacustrine station [10,607 stalks/$m^2$ (±5.8)] (Figure 15). The ANOVA test for temporal distribution did not exhibit significant differences (*p-value = 0.67, F = 0.41*) in densities of *U. gracilis* among sampling dates (Appendix CA61) nor by sampling stations (*p-value = 0.16, F 1.99*) ( Appendix CA62). In La Plata Reservoir, a positive correlations were found between *Urnatella* and DO concentrations ($r^2 = 0.31$, *p-value = 0.0028*) and gravel percent in sediments ($r^2 = 0.27$, *p-value = 0.006*) (Appendices CA63 and CA65), and negative correlations were obtained between the ectoprocts and TN concentrations ($r^2 = 0.17$, *p-value = 0.034*) (Appendix CA64) and the sand ($r^2 = 0.26$, *p-value = 0.006)* and silt percents ($r^2 = 0.21$, *p-value = 0.017*) (Appendices CA66 and CA67).

Figure 14. Estimated densities of *U. gracilis* by sampling dates for (A) Guajataca Reservoir and (B) La Plata Reservoir.

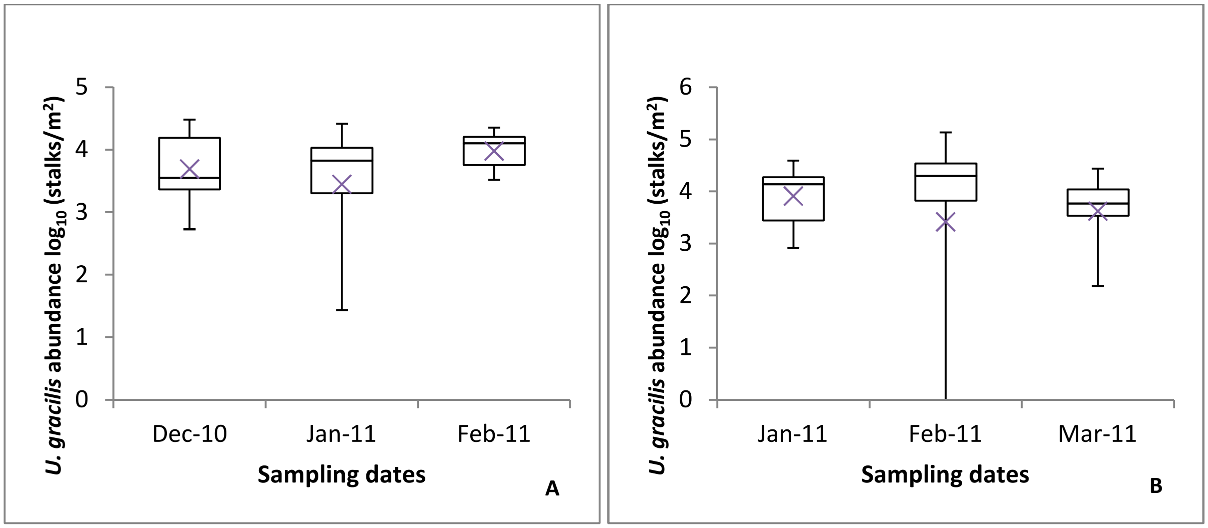



Figure 15. Estimated densities of *U. gracilis* in stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.

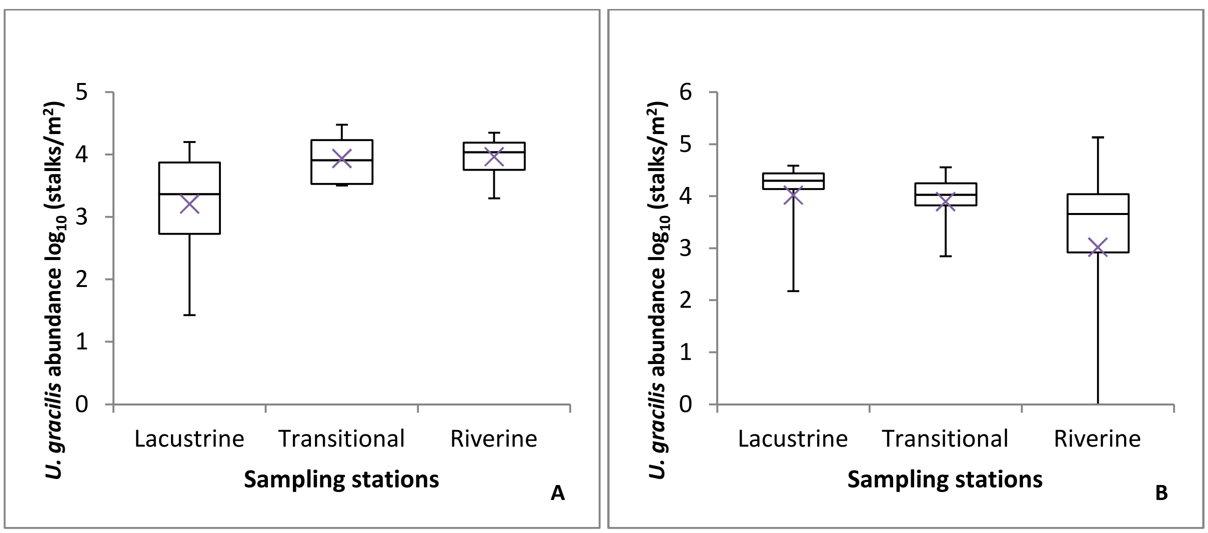


Table 13. *Urnatella gracilis* mean densities by sampling dates for Guajataca and La Plata Reservoirs (stalks/m$^2$).

| | | Sampling dates | | | |
|---|---|---|---|---|---|
| *Reservoir* | | *Dec-10* | *Jan-11* | *Feb-11* | *Mar-11* |
| ***Guajataca*** | ***mean*** | 4,932 | 2,809 | 9,563 | n/a |
| | ***sd*** | 8.3 | 2.5 | 2.3 | n/a |
| | ***upper limit*** | 1,825 | 1,798 | 1,744 | n/a |
| | ***lower limit*** | 1,332 | 1,096 | 1,475 | n/a |
| ***La Plata*** | ***mean*** | n/a | 8,177 | 2,240 | 4,183 |
| | ***sd*** | n/a | 3.5 | 93.6 | 5.1 |
| | ***upper limit*** | n/a | 2,672 | 4,411 | 1,848 |
| | ***lower limit*** | n/a | 2,014 | 1,486 | 1,282 |

Table 14. *Urnatella gracilis* mean densities in stations for Guajataca and La Plata Reservoirs (stalks/m$^2$).

| | | *Stations* | | |
|---|---|---|---|---|
| | | *Lacustrine* | *Transitional* | *Riverine* |
| ***Guajataca*** | ***mean*** | 1,628 | 8,739 | 9,312 |
| | ***sd*** | 8.3 | 2.5 | 2.3 |
| | ***upper limit*** | 993 | 1,976 | 1,914 |
| | ***lower limit*** | 617 | 1,612 | 1,588 |
| ***La Plata*** | ***mean*** | 10,607 | 7,951 | 909 |
| | ***sd*** | 5.8 | 3.3 | 65.9 |
| | ***upper limit*** | 5,112 | 2,454 | 1,578 |
| | ***lower limit*** | 3,450 | 1,875 | 577 |

**Diversity Indices**

Diversity ($\bar{d}$)

The species diversity values ($\bar{d}$) were calculated for the benthic invertebrate communities of Guajataca and La Plata Reservoirs at temporal and spatial levels (Table 15). In Guajataca Reservoir the species diversity ranged from 1.19 at the lacustrine station during January 2011, to 1.63 at the transitional station in December 2010, with an overall mean value of 1.40. Analysis of variance does not show significant differences among stations (*p-value = 0.06, F = 4.55*) for Guajataca Reservoir (Appendix DI1).

In La Plata Reservoir the species diversity ranged from 1.18 in the transitional station during January 2011, to 1.64 in the lacustrine station in March 2011, with an overall mean value of 1.41 for the reservoir. The ANOVA test demonstrated no significant differences (*p-value = 0.06, F = 4.62*) among the species diversity values for La Plata Reservoir (Appendix DI2).

Richness (R)

Richness values were calculated for the benthic invertebrate communities of both reservoirs (Table 15). Richness values for Guajataca Reservoir ranged from 1.41 in the transitional station during December 2010, to 1.84 in the riverine station in February 2011, with a mean of 1.68 for the reservoir. The ANOVA test did show significant differences (*p-value = 0.51, F = 0.75*) among the richness values of Guajataca Reservoir (see Appendix DI3).

The richness values for La Plata Reservoir ranged from 1.28 in the transitional station, during February 2011, to 2.13 in riverine station in January 2011, with an overall value of 1.60. The analysis of variance showed significant differences (*p-value = 0.04, F = 5.60*) in the species richness values among the sampling stations (Appendix DI4). Tukey-Kramer Multiple

Comparisons showed differences between the means of the transitional and riverine stations (DI5).

Evenness (e)

The evenness values were calculated for both reservoirs by each sampling date (Table 15). The values in the Guajatca Reservoir ranged from 0.30 in the lacustrine station, in January 2011, to 0.42 in the transitional station during December 2010, with a mean of 0.35 for the reservoir. Analysis of variance indicated that there were significant differences (*p-value = 0.05, F = 5.02*) on the evenness values for Guajataca Reservoir (Appendix DI6). Tukey-Kramer Multiple Comparisons showed differences between means of the lacustrine and transitional stations (Appendix DI7).

The values in La Plata Reservoir ranged from 0.31 in the riverine station, during January 2011 and March 2011, to 0.40 in the lacustrine and transitional stations during January 2011 and March 2011, respectively. The mean evenness value for the reservoir was 0.36. The ANOVA test showed that significant differences exist (*p-value = 0.02, F = 8.89*) in the species evenness values in La Plata Reservoir among sampling dates (Appendix DI8). Tukey-Kramer Multiple Comparisons showed differences between the means of the lacustrine and riverine stations (Appendix DI9).

Jaccard's Index

For both reservoirs there is 62% of similarity on the macroinvertebrates communities.

Table 15. Species diversity (d), richness (R), and evenness (e) values calculated for benthic macroinvertebrates community of Guajataca and La Plata Reservoirs.

| | | **Lacustrine** | | | **Transitional** | | | **Riverine** | | | ***mean*** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Reservoir* | | *d* | *R* | *e* | *d* | *R* | *e* | *d* | *R* | *E* | *d* | *R* | *e* |
| ***Guajataca*** | ***December 2010*** | 1.36 | 1.76 | 0.33 | 1.63 | 1.41 | 0.42 | 1.33 | 1.57 | 0.34 | 1.44±0.17 | 1.58±0.17 | 0.36±0.05 |
| | ***January 2011*** | 1.19 | 1.69 | 0.3 | 1.55 | 1.76 | 0.37 | 1.4 | 1.75 | 0.34 | 1.38±0.18 | 1.73±0.04 | 0.34±0.03 |
| | ***February 2011*** | 1.29 | 1.72 | 0.32 | 1.38 | 1.64 | 0.35 | 1.43 | 1.84 | 0.34 | 1.37±0.07 | 1.73±0.1 | 0.34±0.01 |
| | ***mean*** | 1.28±0.09 | 1.72±0.03 | 0.32±0.01 | 1.52±0.13 | 1.61±0.18 | 0.38±0.04 | 1.39±0.05 | 1.72±0.14 | 0.34±0.001 | $\bar{X}$ =1.4 | $\bar{X}$ =1.7 | $\bar{X}$ =0.35 |
| ***La Plata*** | ***January 2011*** | 1.58 | 1.48 | 0.4 | 1.18 | 1.4 | 0.33 | 1.31 | 2.13 | 0.31 | 1.36±0.20 | 1.67±0.4 | 0.35±0.05 |
| | ***February 2011*** | 1.45 | 1.31 | 0.39 | 1.36 | 1.28 | 0.38 | 1.31 | 1.61 | 0.34 | 1.37±0.07 | 1.40±0.18 | 0.37±0.03 |
| | ***March 2011*** | 1.64 | 1.76 | 0.39 | 1.52 | 1.42 | 0.4 | 1.31 | 2.03 | 0.31 | 1.49±0.17 | 1.73±0.31 | 0.37±0.05 |
| | ***mean*** | 1.56±0.1 | 1.52±0.22 | 0.40±0.01 | 1.35±0.17 | 1.36±0.08 | 0.37±0.04 | 1.31±0 | 1.92±0.28 | 0.32±0.01 | $\bar{X}$ =1.41 | $\bar{X}$ =1.6 | $\bar{X}$ =0.36 |

**Physicochemical Parameters**

Reservoir Water Level

The water levels in Guajataca Reservoir during December 2010 to March 2011 ranged from 193.2 (February 2011) to 194.8 meters above sea levels (December, 2010), demonstrating that fluctuations were detected in a short sampling period. The water levels for La Plata Reservoir during January 2011 to March 2011 varied very little, from 51.5 (March 2011) to 51.8 meters above sea levels (January and February 2011).

Water Temperature

The water temperature in Guajataca Reservoir between December 2010 and February 2011 ranged from 25.7- 27 ºC, with a mean temperature of 26.2 ± 0.12 ºC. The lacustrine station had the lowest mean temperature with 26.0± 0.12 ºC. The riverine station had the highest mean temperature with 26.5 ± 0.21ºC (Figure 16). One way ANOVA test showed no significant differences (*p-value = 0.32, F= 1.20*) in the temperature between the sampling dates; but there were significant differences (*p-value = 0.001, F= 8.70*) between stations (Appendices PP1 and PP2). Tukey- Kramer Multiple Comparisons test showed differences among the means of lacustrine and riverine stations (Appendix PP3).

The water temperature recorded in this study for La Plata Reservoir ranged from 25.2 ºC at the riverine station during February 2011 to 28.2 ºC at the transitional station during March 2011, with a mean temperature of 26.9 ± 0.31 ºC for the reservoir. The lacustrine station had the lowest mean temperature with 26.8± 0.49 ºC. The highest mean temperature was recorded at the transitional station with 27.0 ± 0.49 ºC (Figure 16). The analysis of variance showed significant differences (*p-value* = $1.83 \times 10^{-11}$, *F = 82.17*) in the water temperature among the sampling dates, but not among the stations (*p-value = 0.83, F= 0.18*) (Appendices PP4 and PP5). Tukey-Kramer Multiple Comparisons showed differences in the mean of water temperature between January and February, and between February and March (Appendix PP6).

Dissolved Oxygen (DO)

Dissolved oxygen for Guajataca Reservoir ranged from 3.87 mg/L in the lacustrine station to 9.05 mg/L in the riverine station, with a mean of 7.12 ± 1.16 mg/L. The lacustrine station had the lowest mean DO concentration with 6.95 ± 1.58 mg/L. Transitional station had the highest mean DO concentration with 7.21 ± 0.57 mg/L (Figure 17). One way ANOVA test showed significant differences (*p-value = 0.000046, F = 15.60*) in the DO levels between sampling dates, but no significant differences (*p-value = 0.89, F= 0.12*) within stations with combined dates (Appendices PP7 and PP8). Tukey-Kramer Multiple Comparisons showed differences in the mean of DO between December and January (Appendix PP9). A positive correlation was found between DO and benthic invertebrates' densities ($r^2 = 0.21$, *p-value = 0.015*) (Appendix PP10).

The DO for La Plata Reservoir ranged from 4.11 mg/L at the riverine station to 9.85 mg/L in the transitional station, with a mean of 7.42 ± 0.52 mg/L for the reservoir. The riverine station had the lowest mean concentration of DO with 7.04 ± 1.11 mg/L. The highest mean concentration of DO was measured at the transitional station with 7.98 ± 0.98 mg/L (Figure 17). The ANOVA test showed significant differences (*p-value = 0.03, F = 4.12*) in the DO levels among sampling dates, but not (*p-value = 0.32, F = 1.18*) among stations (Appendices PP11, and PP12). Tukey-Kramer Multiple Comparisons showed differences in mean of dissolved oxygen between January and March (Appendix PP13).

Secchi Depth (SD)

The secchi depth values obtained for Guajataca Reservoir ranged from 0.6 in the transitional station to 3.5 m in lacustrine station, with a mean value of 1.27 ± 0.24 meters. The riverine station had the lowest mean SD value with 0.91 ± 0.17 m, and the lacustrine station had the highest mean SD value with 1.79 ± 0.53 m (Figure 18). The ANOVA test showed no significant differences in the SD value among sampling dates (*p-value = 0.64, F= 0.45*) and stations (*p-value = 0.07, F= 2.89*) for Guajataca Reservoir (Appendices PP14 and PP15).

The secchi depth values obtained for La Plata Reservoir ranged from 0.4 to 1.7 m, with a mean value of 0.94 ± 0.13 m. The lowest mean SD value was obtained at the riverine station with 0.62 ± 0.11 m. The lacustrine station had the highest mean SD value with 1.23 ± 0.22 m (Figure 18). The ANOVA test did not show significant differences (*p-value = 0.32, F = 1.19*) in the SD value among sampling dates, meanwhile significant differences (*p-value = 0.0001, F = 13.30*) were seen among sampling stations for La Plata Reservoir (Appendices PP16 and PP17). Tukey-Kramer tests showed differences in means of the lacustrine and riverine, and between the transitional and riverine stations (Appendix PP18).

pH

The pH value for Guajataca Reservoir was slightly alkaline. The values ranged from 7.92-8.10 both in the lacustrine station, with a mean $[H^+]$ value of $9.47 \times 10^{-9}$. The lacustrine tation had the lowest $[H^+]$ value with $9.77 \times 10^{-9}$, and the riverine station had the highest $[H^+]$

value with 1.03 x $10^{-8}$, see Figure 19. One way ANOVA did not show significant differences (*p-value = 0.29, F = 1.58*) in the pH values between stations (Appendix PP19). A positive correlation was found between pH and benthic community abundances ($r^2 = 0.31$, *p-value = 0.003*) (Appendix PP20).

The pH values for La Plata Reservoir were alkaline, ranging from 8.37 at the lacustrine station to 8.68 at the riverine station, with a mean $[H^+]$ value of 2.75 x $10^{-9}$ for the reservoir. The riverine station had the lowest mean $[H^+]$ value with 2.55 x $10^{-9}$ and the highest mean $[H^+]$ value was at the lacustrine station with 3.04 x $10^{-9}$ (Figure 19). The analysis of variance showed no significant differences (*p-value = 0.67, F = 0.42*) in the pH values among stations (Appendix PP21).

Chlorophyll *a* (Chl A)

The concentrations of chlorophyll *a* for Guajataca Reservoir ranged from 2.22- 6.55 µg/L, with a mean concentration of 3.44 ± 0.82 µg/L. The lowest concentration of Chl A was detected in the lacustrine station with a mean of 2.62 ± 0.39 µg/L. The highest concentration was reported at the riverine station with a mean of 4.41 ± 2.14 µg/L (Figure 20). One way ANOVA did not show significant differences (*p-value = 0.23, F = 1.87*) in the Chl A concentrations among stations (Appendix PP22).

The concentrations of chlorophyll *a* for La Plata Reservoir ranged from 13.6 µg/L in the lacustrine station to 154.5 µg/L in the transitional station, with an overall mean concentration of 46.6 ± 29.4 µg/L. The lowest mean concentration of Chl A was recorded in the lacustrine station (15.1 ± 1.83 µg/L), while the highest concentration was obtained at the transitional station (69.4 ± 84.0 µg/L), see Figure 20. The ANOVA test showed no significant differences (*p-value = 0.35, F = 1.25*) in the Chl A concentrations among sampling stations (Appendix PP23).

Total Phosphorus (TP)

The total phosphorus concentration in Guajataca Reservoir ranged from 0.006- 0.011 mg/L, with a mean concentration of 0.008 ± 0.001 mg/L. The lowest concentration was at the transitional station with a mean of 0.006 ± 0.0004 mg/L. The highest mean concentration of TP was recorded at the riverine station with 0.010 ± 0.001 mg/L (Figure 21). The ANOVA test showed significant differences (*p-value = 0.01, F = 9.17*) in the TP concentrations among stations (see Appendix PP24). Tukey-Kramer Multiple Comparisons showed differences among means of the transitional and riverine stations (Appendix PP25). A negative correlation was found between the concentrations of TP and the benthic community abundances ($r^2 = 0.17$, *p-value = 0.030*) (see Appendix PP26). A positive correlation was observed between TP and Chl A concentrations ($r^2 = 0.28$, *p-value = 0.004*), (Appendix PP27). A negative correlation was obtained between TP and DO concentrations ($r^2 = 0.15$, *p-value = 0.042*) (Appendix PP28).

The concentration of TP in La Plata Reservoir ranged from 0.035 mg/L in the transitional station to 0.088 mg/L in the riverine station, with a mean concentration of 0.057 ± 0.012 mg/L. The lowest concentration was detected at the lacustrine station (0.042 ± 0.007 mg/L). The highest mean concentration of TP was recorded at the riverine with 0.073 ± 0.014 mg/L (Figure 21). The ANOVA test did not show significant differences (*p-value = 0.08, F = 3.96*) in the TP concentrations among stations (Appendix PP29). A negative correlation was found between TP concentrations and benthic invertebrates' abundances ($r^2 = 0.22$, *p-value*

*= 0.014)* (Appendix PP30). Also, a positive correlation was detected between TP and Chl A concentrations ($r^2$ *= 0.30, p-value = 0.003*) for this reservoir (Appendix PP31).

Total Kjeldahl Nitrogen (TKN)

The total nitrogen concentration for Guajataca Reservoir had a mean value of 0.45 ± 0.28 mg/L. The lowest mean concentration was detected in the riverine station with 0.37 ± 0.06 mg/L. The highest mean concentration value was measured in the transitional station with 0.76 ± 0.80 mg/L (Figure 22). The ANOVA test showed no significant differences (*p-value = 0.56, F = 0.63*) in the TKN concentrations among the stations (Appendix PP32).

The TKN concentration for La Plata Reservoir ranged from 0.41 mg/L in the transitional station to 0.78 mg/L in the riverine station. The mean concentration value for the reservoir was 0.55 ± 0.09 mg/L. The lowest TKN mean concentration was measured in the lacustrine station with 0.46 ± 0.03 mg/L. The highest TKN mean concentration value was in the riverine station with 0.68 ± 0.14 mg/L (Figure 22). The ANOVA test showed no significant differences (*p-value = 0.10, F = 3.38*) in the TKN concentrations among the sampling stations in La Plata Reservoir (Appendix PP33). Negative correlation were found between TKN concentrations and benthic community abundances ($r^2$ *= 0.51, p-value = 0.00003*) (Appendix PP34). A positive correlation between TKN and Chl A concentrations was detected ($r^2$ *= 0.40, p-value = 0.0004*) (Appendix PP35).

Sediment Analyses

The results of sediment analyses for the sampling stations of Guajataca Reservoir are shown in Table 16. The lowest gravel percent was observed in the riverine station. The highest gravel percent was reported at the lacustrine station. The lowest sand percent was seen at the lacustrine station, while the highest percent was at the riverine station. Silt comprised less than 5% of the samples. The lowest silt percent was reported at the lacustrine station, while the highest percent was in the riverine station.

The results of the sediment analyses for the sampling stations of La Plata Reservoir are reported in Table 16. The lowest gravel percent was recorded in the riverine station and the highest was measured at the lacustrine station. The lowest sand percent was recorded in the lacustrine station and the highest in the riverine station. In this reservoir silt comprised less than 2.5% of the sediments. The lowest silt percent was measured in the lacustrine station, while the highest was reported in the riverine station.

Table 16. Sediment analyses in stations for Guajataca and La Plata Reservoirs.

| | | **Percent by weight** | | |
|---|---|---|---|---|
| *Reservoir* | *Stations* | *Gravel* | *Sand* | *silt* |
| ***Guajataca*** | ***Lacustrine*** | 70.7 | 28.1 | 1.2 |
| | ***Transitional*** | 44.9 | 53 | 2.1 |
| | ***Riverine*** | 28.2 | 67.4 | 4.4 |
| ***La Plata*** | ***Lacustrine*** | 67.3 | 32.1 | 0.6 |
| | ***Transitional*** | 49 | 49.9 | 1.1 |
| | ***Riverine*** | 41.1 | 56.9 | 2 |

Figure 16. Water temperature in sampling stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.

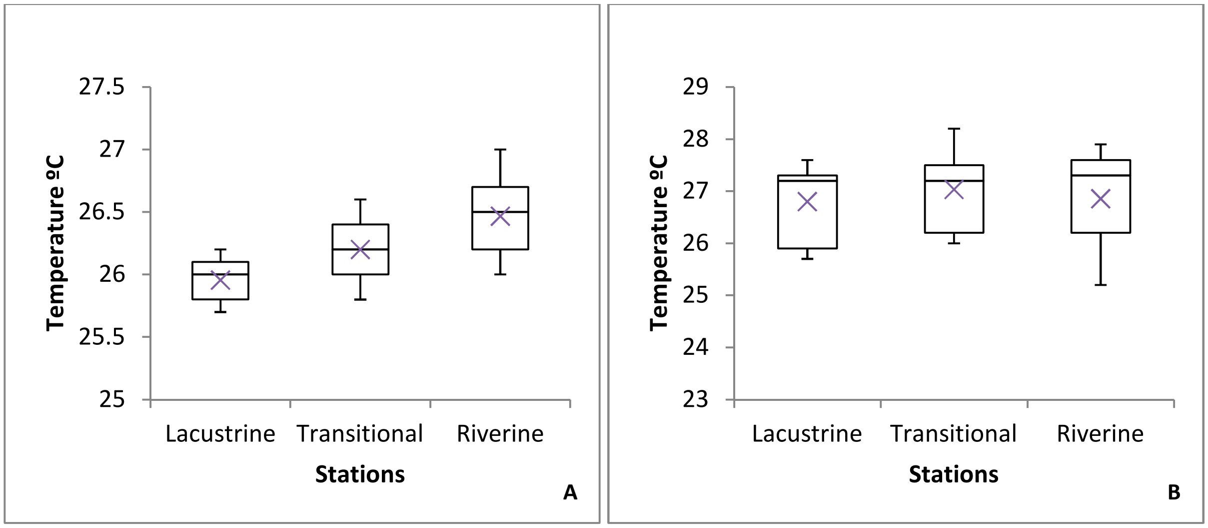



Figure 17. Dissolved oxygen concentrations in stations for (A) Guajataca Reservoir and (B) La Plata Reservoir

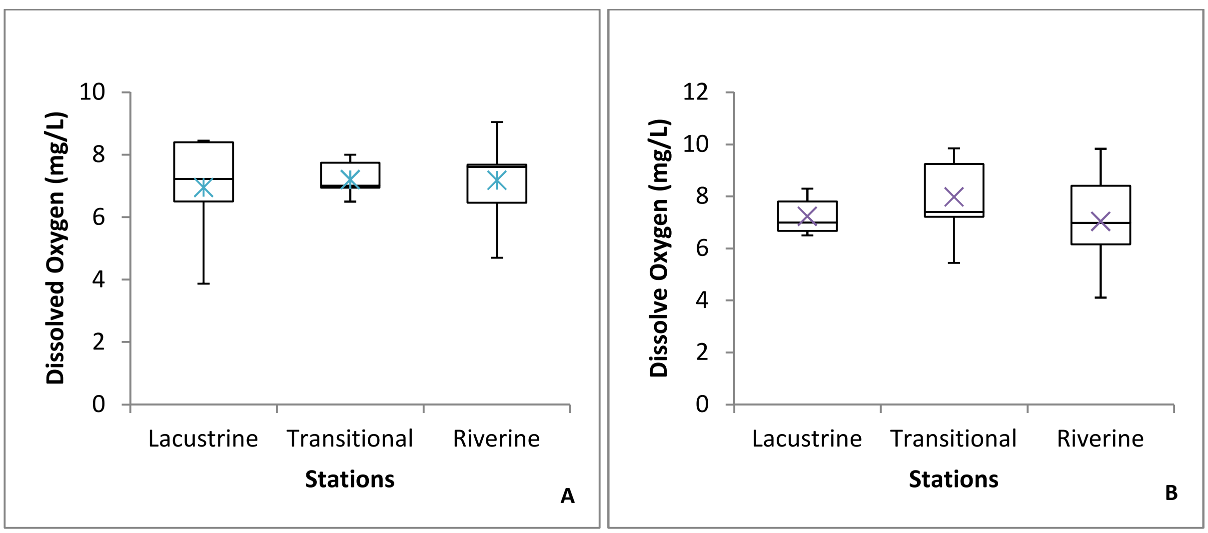


Figure 18. Secchi disk depth in stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.

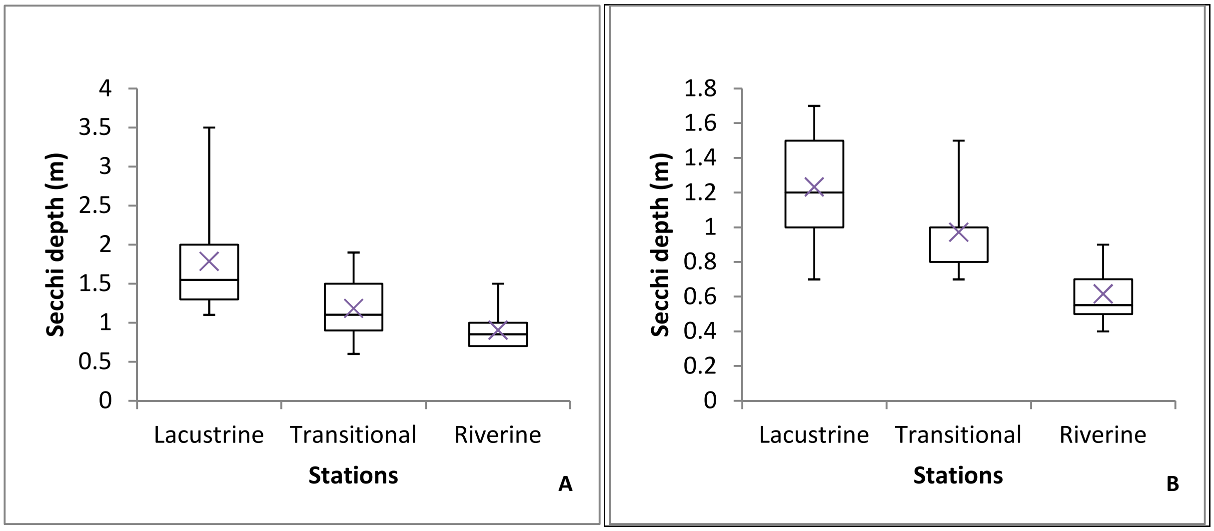



Figure 19. Mean pH values in stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.

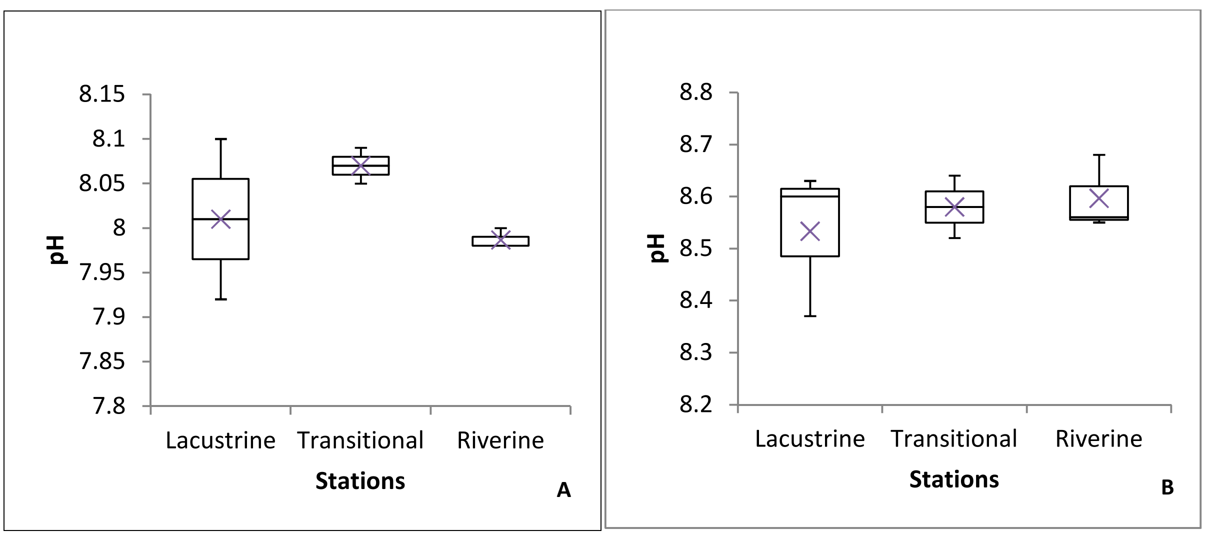


Figure 20. Mean chlorophyll a concentrations in the stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.

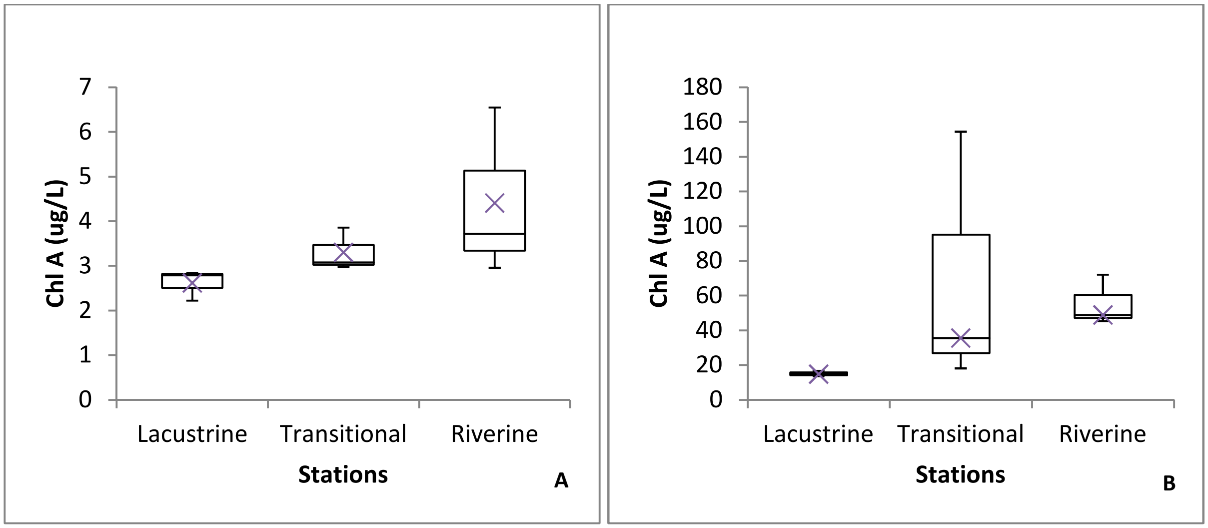



Figure 21. Mean total phosphorus concentrations in the stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.

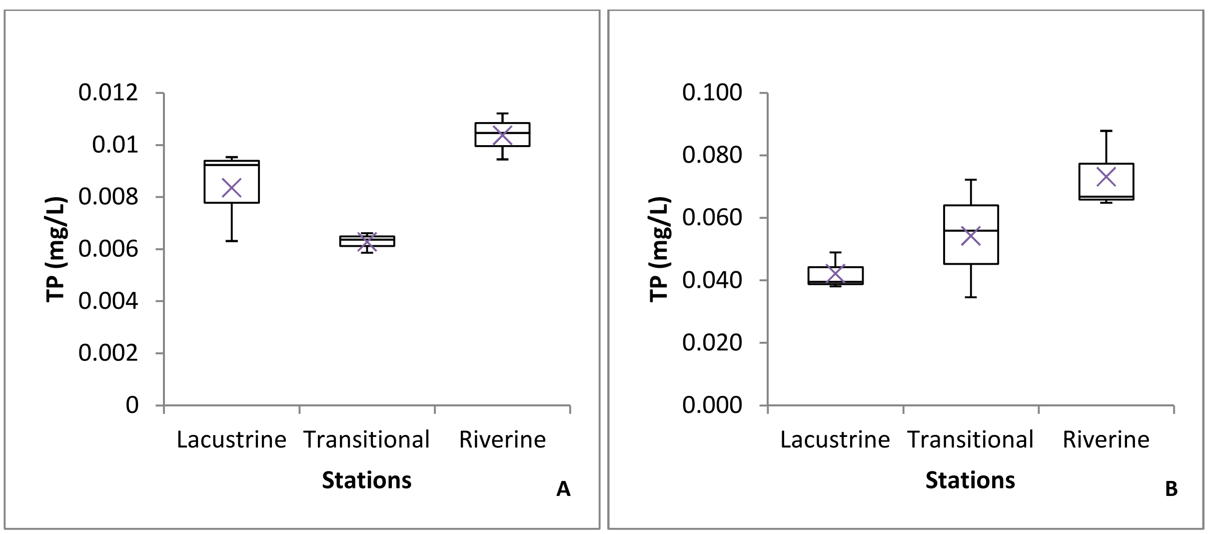
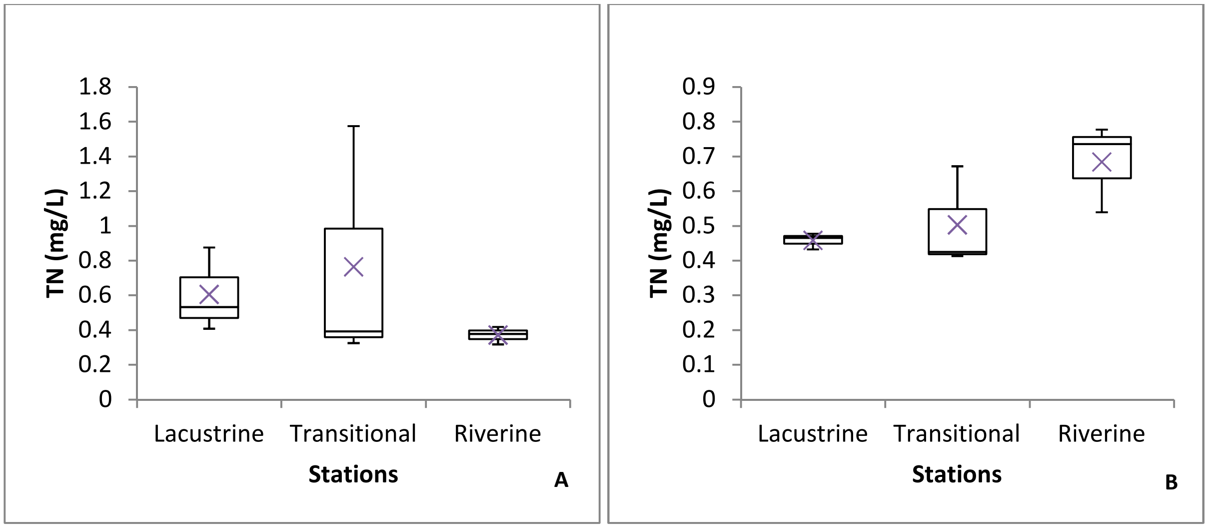


Figure 22. Mean total nitrogen concentrations by the stations for (A) Guajataca Reservoir and (B) La Plata Reservoir.



# Discussion

The benthic macroinvertebrates communities in Guajataca and La Plata Reservoirs were dominated by organisms belonging to the class Gastropoda, in contrast to the Pérez and Fresneda (1976) study of benthic communities in Ejército Rebelde Reservoir that were dominated by members of Insecta and Oligochaeta. Others classes like Bivalvia, Phylactolaemata, Clitellata, Turbellaria, Hydrozoa, Insecta, Ostracoda, Cephalocarida, and Malacostraca were also found. The phylum Entoprocta was reported for first time on the Island.

The class Gastropoda consisted primarily of individuals from the families: Thiaridae, Hydrobiidae, and Ancylidae. They accounted for 71.7% of the total organisms collected in the study. These three families were documented for the island in previous studies (Schalie, 1948; Chaniotis et al., 1980). Indeed, a fair number (4-6) of gastropods represent new records for the Island or are new species, reflecting the understudied state of this particular fauna. The family Thiaridae comprised the 95.1% of all gastropods collected, mainly represented by the alien species *Tarebia granifera.*

The mean zoobenthic community density of Guajataca Reservoir (61,042 organisms/$m^2$) was higher than the mean zoobenthic community density of La Plata Reservoir (37,485 organisms/$m^2$). Although the densities were different these reservoirs, the diversity, evenness, and richness categorizations were similar between them. The diversity index for these reservoirs ranged from 1.18 to 1.64, which is indicative of moderately polluted systems (Ferraris and Wilhm, 1976). The evenness value indicates how evenly distributed the species are in the community; values can range from 0 to 1, with higher values indicating more even distribution.

The evenness values for both reservoirs ranged from 0.30 to 0.42. Values below 0.5 indicate water affected by oxygen demanding wastes (Klemm et al., 1990).

Richness values relate the number of species compared to the number of individuals present (Margalef, 1957). The richness values for Guajataca and La Plata reservoirs ranged from 1.3 to 2.1. Values less than 1 indicate poor community richness, values 1 to 3 indicate moderate community richness, and values over 3 indicate high community richness.

Contrasting other studies (Ali et al., 2003; Sousa et al., 2007; Prater, 1991), no significant correlation was found between the benthic community abundances and the type of sediments in this study. Although it can be noticed that the highest mean densities of benthic invertebrates in both reservoirs were in the stations with more than 40% of sand, it is necessary to consider physicochemical parameters and environmental changes for each site. Of the indicators of eutrophication measured in this study (Chl A, TKN, DO and TP), TP concentrations were negatively correlated with the benthic community abundances in both reservoirs. Also the TP concentrations were positively correlated with Chl A concentrations for both reservoirs. It is well known that phosphorus concentrations limit the phytoplankton productivity.

In Guajataca Reservoir the TP concentrations were negatively correlated with DO concentrations. Meanwhile, the DO concentrations and benthic community densities were positively correlated in this reservoir. In very productive lakes, decomposition of sedimented organic matter produces anoxic conditions, which can affect the abundance and distribution of benthic organisms (Wetzel, 2001). It is probable that the low DO conditions prevailing in La Plata Reservoir precluded us from seing a relationship between DO and invertebrates' abundances.

This study was just a preview of the zoobenthic communities in the Island's reservoirs. Several studies in Puerto Rico are been related with the characterization of the macroinvertebrates in sporadic collections, but never in an exhausted study. The new reports of species such as: *Aylacostoma cf. pulcher*, *Potamopyrgus antipodarum*, *Elimia cf.*, and *U. gracilis* demonstrates how unstudied are been the benthic communities in these freshwater systems. The the dynamics of these organisms and the macroinvertebrates communities in the Island's reservoirs still been unknown. It is necessary to performs more studies in these and others lentic systems to understand better the macroinvertebrates communities in Puerto Rico.

**Guajataca Reservoir**

According to Amador et al. (2008) Guajataca Reservoir is classified as mesotrophic by the Trophic State Index. In this reservoir the littoral benthic community is dominated by *T. granifera* (mean 43,022/$m^2$), followed by *Urnatella gracilis* (mean 5,097/$m^2$), the complex *Pyrgophorus/Potamopyrgus* (mean 1,961/$m^2$), *Corbicula fluminea* (mean 1,754/$m^2$), Ostracoda (mean 1,177/$m^2$), and others (mean 578/$m^2$). The "others" group includes organisms that occured in lower densities, were rare and are unknown species. The organisms with low densities were: Diptera (mean 23/$m^2$), Hirudinea (mean 2/$m^2$), Oligochaeta (mean 27/$m^2$), *Melanoides tuberculata* (mean 1/$m^2$), *Ferrissia irrorata* (mean 44/$m^2$), *Gundlachia radiata* (mean 7/$m^2$), *Pomacea cumingi* (mean 4/$m^2$), *Marisa cornuarietis* (mean 3/$m^2$), *Pisidium casertanum* (mean 2/$m^2$), and *Plumatella repens* (mean 3/$m^2$).

Rare organisms were those with less than ten individuals encountered in the whole study. These were: Hemiptera, Cladocera, Nematoda, Turbellaria, *Physa cubensis, Physa marmorata, Menetus* cf. *dilatatus, Hydra viridis,* and *Eupera* cf. *portoricensis*. Although the physicochemical parameters of this reservoir are characteristic of mesotrophic systems, the zoobenthic community densities (over 1,000 organisms/$m^2$) are indicative of eutrophic systems (Brinkhurst, 1974).

As mentioned before, in this reservoir the benthic community densities are related with highest dissolved oxygen levels. It is important to mention that the lowest DO concentration (3.87 mg/L) was recorded in the lacustrine station during evening. This indicates that the benthic organisms that inhabit this reservoir probably are capable of tolerating even lower oxygen concentrations during night time.

**La Plata Reservoir**

This reservoir is classified as eutrophic according to the Trophic State Index (Amador et al., 2008). The benthic community exceeded the 1,000 organisms/$m^2$; using Brinkhurst (1974) benthic classification it can be said that this system is eutrophic. As in Guajataca Reservoir, the organism that dominated the benthic community in La Plata Reservoir was *T. granifera* (mean 11,590/$m^2$). It was followed by an array of species similar to that observed in Guajataca Reservoir: *U. gracilis* (mean 4,248/$m^2$), Ostracoda (mean 465/$m^2$), the Complex *Pyrgophorus/Potamopyrgus* (mean 349/$m^2$), Diptera (mean 211/$m^2$), others (mean 201/$m^2$), *C.fluminea* (mean 194/$m^2$), and Oligochaeta (mean 174/$m^2$). Also in this reservoir, the "others" group includes organisms that occur in lower densities, rare organisms and unknown species. Organisms found at low densities were *M. tuberculata* (mean 14/$m^2$), *P. repens* (mean 12/$m^2$), Hirudinea (mean 5/$m^2$), *F. irrorata* (mean 1/$m^2$), Nematoda (mean 1/$m^2$), Turbellaria (mean 1/$m^2$), and Amphipoda (mean 1/$m^2$). The rare organisms (less than ten individuals in whole study) were: *P. casertanum*, *G. radiata, P.cumingi, P. marmorata, M. cornuarietis, A. cf. pulcher,* Hemiptera, Cladocera, Ephemeroptera, Coleoptera, *H. vulgaris*, and *Physa sp*.

In this reservoir no significant relationship was found between the DO concentration and zoobenthic community abundances. However, it is important to emphasize that the riverine station had the lowest mean density and it coincided with the lowest DO concentration. If the lowest DO concentration recorded for this reservoir was 4.11 mg/L during day time, the organisms that inhabit this station must be capable of tolerating low oxygen or hypoxia during night. The most abundant organism in this station was *T. granifera.* According with Mackie and Claudi (2010), these relatively low DO concentrations are suitable to promote nuisance infestations of this species.

***Corbicula fluminea***

The Asian clam populations composed less than 5% of the total zoobenthic community in both reservoirs. This results contrast with the studies of Karatayev et al. (2003) and Sousa et al. (2008b), in which *C. fluminea* was the dominant species of the benthic fauna. The *C. fluminea* mean density in Guajataca Reservoir (1,754/$m^2$) is very similar to the densities found in the Paraná River Delta in Argentina (mean 1,070/$m^2$) by Cataldo and Boltovskoy (1999), in Lake Constance in Central Europe (2,000/$m^2$) by Werner and Rothhaupt (2007) and in the Minho Estuary in Portugal (777/$m^2$ to 1,200/$m^2$) by Ilarri et al. (2011).

The first report of this species in La Plata Reservoir presented a density of 10/$m^2$ (Williams et al., 2001). Today, the mean density of *C. fluminea* in shallow areas of the same reservoir is 204/$m^2$. The mean density of La Plata is very similar to densities reported in Poyang Lake in China (156/$m^2$) by Wang et al. (2007), Paranoá Lake in Brazil (300/$m^2$) by Rodrigues et al. (2007), and in Lake Nocogdoches in Texas (172/$m^2$) by Karatayev et al. (2003).

According to Mackie and Claudi (2010), dissolved oxygen concentrations over 2 mg/L allows moderate to massive infestations of the Asian clam. The oxygen uptake of *C. fluminea* is regulated by temperature. Increasing temperatures up to 25 ºC, increases uptake rate, but this uptake decreases at 30 ºC (*Ibid*). In this study no significant correlation was found between DO concentrations, water temperatures, and clam densities. However, it was observed that the transitional stations of both reservoirs had the highest DO concentrations and also the highest *C. fluminea* mean densities. Sousa et al. (2008a) found that DO concentrations between 5.5 mg/L to 11.3 mg/L did not affect the abundance and biomass of the clams. Negative correlations were obtained between TP concentrations, pH, and *C. fluminea* densities. High TP concentrations and alkaline waters are characteristics of eutrophic systems. These results are in accordance with those of Sousa et al. (2008a), in which the concentrations of nutrients were negatively correlated with clam abundance. They concluded that this species is sensitive to pollutants and not well adapted to enriched conditions.

The characteristics of sediments are reported to be important in the distribution of this species (Karateyev et al., 2003; Sousa et al., 2008b). Karatayev et al. (2003) indicate that the clams were more abundant in sediments formed by shells and course detritus and least abundant in silt. No correlation was found between sediments and *C. fluminea* abundance; however, the highest densities of clams were noted in the transitional stations which had the lowest gravel and silt percents and highest sand percent. This result agrees with the study by Sousa et al. (2008a), which correlated the higher biomass of *C. fluminea* with the higher coarse sand values.

This study shows that *C. fluminea* is the most abundant bivalve in the benthic communities of shallow areas in both reservoirs. In Guajataca Reservoir, the spatial distribution of *P. casertanum* and *C. fluminea* overlaps in the lacustrine and transitional stations but the densities of *P. casertanum* are very low compared to *C. fluminea* densities. According to Vaughn and Spooner (2006) and Sousa et al. (2007), the high filtering rates of *C. fluminea* and the ability to pedal feed may affect the patterns and distribution of native mussels. Contrasting Karatayev et al. (2003), these data suggest that *C. fluminea* population is affecting the native bivalve species. The lack of previous information about the distribution patterns and densities of *E. portoricensis* and *P. casertanum* in local reservoirs does not allow an estimate of the magnitude of the effects of the Asian clam on native clams. However, it is quite evident that exotic species massively outnumbered the native clams in both reservoirs.

The Asian clam populations in Guajataca and in La Plata reservoirs are dominated by small-sized individuals and juveniles. Over 96% of the clams collected in both reservoirs belong to the size classification of 0-13 mm (Class I). According to Cataldo and Boltovskoy (1999), the estimated size range for one-year-old individuals was 15.3-22.4 mm, for two years: 23.5-27 mm, and three years: 27.5-29.3 mm. Therefore, the clam populations in both reservoirs seem dominated by individuals of less than one-year-old. This result contrasts with the work by Cohen et al. (1984), in which this Class I composed only 20% of the total clams collected in the Potomac River. Due to the fact that *C. fluminea* populations in Guajataca and La Plata reservoirs consist of small and juvenile individuals, mortality of adults must be high. Shallow areas within the reservoirs (0-6 m deep) were selected to set the sampling stations because it was known *a priori* that deeper areas were mostly hypoxic or anoxic and, therefore, devoid of living Asian clams. According with Sousa et al. (2008a), the species is not well adapted to enrichment conditions. The high nutrient levels seem problematic for survival and development of juveniles, which could explain the relatively lower densities observed for the clam in the hypereutophic La Plata Reservoir.

***Tarebia granifera***

The quilted melania or *Tarebia (Thiara) granifera* is a member of Thiaridae, and originally came to the Americas from Southeast Asia. Like many other exotic molluscs, this species has very successfully invade freshwater systems from North and South America to the Caribbean region (Pointer et al., 2001; Rodríguez et al., 2003; Karatayev et al., 2009). This species was introduced to Puerto Rico around 1954 by unknown circumstances (Harry and Aldrich, 1958) and can be found in the shallow waters of almost any freshwater body, including rivers, streams, lakes, irrigation canals, cement ponds, and wetlands (Chaniotis et al.,1980a). Being ovo-viviparous and parthenogenetic, allowes this species to produce abundant populations in a short time (Harry and Aldrich, 1958). Its reproductive and invasive characteristics enable *T. granifera* to be used as a biocontrol for *Schistosoma mansoni* hosts such as *Biomphalaria spp.* (Pointer et al., 2001). Furthermore, *T. granifera* serves as intermediate host of the lung fluke (*Paragonimus westermani).* This trematode parasitizes humans, by the ingestion of raw freshwater crustaceans infected as second intermediate hosts (Lachner et al., 1970).

The quilted melania dominates the benthos of both reservoirs. The mean density for Guajataca Reservoir was 43,021/$m^2$ and for La Plata Reservoir was 11,590/$m^2$. The mean density of *T. granifera* in Guajataca Reservoir is much higher than the densities reported by Appleton et al. (2009) for seven different systems in South Africa (843/$m^2$ to 20,764/$m^2$), and by López-López et al.(2009) in Tuxpam (100/$m^2$ to 1,000/$m^2$) and Tecoluta (> 100/$m^2$) rivers in Mexico. This species is also present in Cuba (Vázquez and Perera, 2010) and its density in a system there was estimated as just 85/$m^2$.

Chaniotis et al. (1990) described this species as the most dominant aquatic snail in Puerto Rico, and described the population density in La Plata Reservoir as moderate (3-5 cm between specimens) but did not report exact density values. In a recent study conducted by Reeves et al. (2008) in Dominica, this species was not collected, probably because it has not been introduced to this island yet.

Several authors present *T. granifera* as a biocontrol for *Biomphalaria glabrata* and *B. straminea*, intermediate snail hosts of *Schistosoma mansoni* (Butler et al., 1980; Pointier, 2001). Although among the aims of the present study were not the impacts of *T. granifera* on the freshwater gastropods populations, it is important to mention that no specimens of *Biomphalaria* spp were collected in the selected stations in Guajataca and La Plata reservoirs.

According with Mackie and Claudi (2010), the nutrient levels required for survival, growth, and reproduction of this species are unknown. In this study negative correlations were found between *T. granifera* densities and TKN and TP concentrations. These results agree with the work by Diéquez et al. (1992), which shows that the population densities are affected by variations in ammonium, nitrates and nitrites. Positive correlations were found between *T. granifera* densities and temperature, pH, DO concentrations, and secchi disk values. Mackie and Claudi (2010) reported that temperatures from 22-36 ºC and pH values from 7.5-8.5 support a high potential for massive infestations of this species. The correlations with DO concentrations and secchi disk values are indicative that the habitats preferred by *T. granifera* are those where high production of oxygen is, mostly from the periphyton which is its main food source. No correlations were seen with Chl A concentrations; although, it must be considered that Chl A determinations were based upon samples collected from the water column (concurrent study by

Jessica Chappell, UPRM), reflective of mainly phytoplanktonic algae, and not from the benthos, where the periphyton grazing by the quilted melania occurs.

***Pyrgophorus/Potamopyrgus* complex**

All the freshwater snails in the family Hydrobiidae that have been reported from the Antilles are classified under the genus *Pyrgophorus* (Ancey, 1888). This genus is known from Texas south to Panama, Colombia, Venezuela, West Indies, and southern Florida, excluding the Bahamas. Many species of this genus have been incorrectly placed in the genus *Potamopyrgus* (Stimpson, 1865), because of the strong similarity of the sculpture on the shell (Thompson, 1968). In the northern Caribbean region, two species are mentioned, *Pyrgophorus coronatus* and *Pyrgophorus parvulus* (Smith and Brousseau, 1996). According to Schalie (1948), *Potamopyrgus coronatus* is a common species in Puerto Rico, with two morphs: smooth shell and spined shell. He sampled three localities on the Island, and reported that the spined individuals were more common in areas near the sea than in freshwater sites. He probably was referring to *P. parvulus*, since this species has the ability to tolerate brackish environments (Smith and Brousseau, 1996; Klosowska et al. 2004). The presence of spines has been an issue for discussion for years. Some authors relate the spinose morph to food sources (Schalie, 1948). Vermeij (1978) proposed that the development of spines is an adaptation to avoid selective predation.

The mean population of this group of aquatic snails in Guajataca Reservoir was 1,961/m$^2$ and for La Plata Reservoir was 349/m$^2$. No correlations were found with substrate and water parameters. However, according with McCrary et al. (2008), the habitats preferred by *Pyrgophorus coronatus* in Lake Xiloa are those with the green algae of the genus *Chara sp.* The population in this kind of habitat was estimated in 3,687 ± 698/m$^2$. Another species in the Antillean “complex”, *Potamopyrgus antipodarum*, can tolerate wide ranges of environmental conditions (Alonzo and Castro-Díez, 2008; Mackie and Claudi, 2010). According with Weatherhead and James (2001), *P. antipodarum* is the dominant macroinvertebrate in New Zealand Lakes (> 180,000/m$^2$) and its abundance is correlated with the presence of macrophytes. In the Yellowstone systems this species has become abundant with densities that reach 300,000/m$^2$, and the abundance of other macroinvertebrates taxa are negatively related with *P. antipodarum* densities (Kerans et al., 2005). The presence of *P. antipodarum* in Guajataca and La Plata reservoirs could affect the populations of the native snails. Future studies are required to monitor the populations of this “complex” of species in the island.

***Urnatella gracilis***

*Urnatella gracilis* (Leidy) is the only known freshwater species in the phylum Entoprocta. This species is a suspension feeder, consuming organic particles, unicellular algae, and other protists. The zooids can attach to almost any substratum, like rocks, molluscan shells, sticks, aquatic plants, and lead fishing weights (Wood, 2010). In a study by Weise (1961), all the specimens were collected in coarse gravel, rubble, and rocks; none were found in sandy or muddy bottoms. *Urnatella gracilis* can live in flowing water or in shallow areas of large lakes (Wood, 2010). This species is known from every continent, except Antarctica and Australia. In North America, its distribution ranges from the east to west coast, and to as far north as Michigan (Wood, 2010). There is no published report of *U. gracilis* from Mexico, Central America or the West Indies (Bushnell, 1984). Bushnell (*Ibid*.), based on suggestive evidence, indicated that this species was absent in equatorial regions, as all records except one for Central

Africa are non-equatorial. The data collected and reported for this species in this study are the first for this geographical area.

In Guajataca Reservoir the mean density of *U. gracilis* was 5,097/$m^2$ and comprised 10.3% of the benthic community. The highest densities occurred in the riverine station, suggesting a good extent of deposition at this point in the reservoir given the fact that entoprocts are sessile suspension feeders. Although no correlations with physicochemical parameters and sediment composition were found for *U. gracilis* in this reservoir, its abundance could be associated with availability of attachment materials. Weise (1961) reported that all the specimens collected were in areas with coarse gravel, rubble or boulders. The sediments of the riverine zone of Guajataca Reservoir are comprised of 67.4 % of sand (Table 6), and also are frequently impacted by trash and organic material that is dragged by runoff.

In La Plata Reservoir, the mean density of *U. gracilis* is 4,247/$m^2$ and comprises 34.8% of the benthic community. It should be stressed that *U. gracilis* is a small animal and its relative abundance, based on number of individuals, overestimates its importance at a biomass scale. In contrast with the data collected in Guajataca Reservoir, in La Plata correlations were found between physicochemical parameters and sediment composition.

According with Wood (2010), *U. gracilis* can tolerate a wide range of chemical and physical conditions. The density data from La Plata Reservoir reflected a positive correlation with DO concentrations and negative correlation with the TKN concentrations. Although *U. gracilis* attaches to almost any substratum (Wood, 2010), positive correlation with gravel percent was found, meanwhile negative correlation was observed with sand and silt percents. This species occurred more often in the lacustrine station of this reservoir. The DO and TKN concentrations for this station had mean values of 7.24 mg/L and 0.46 mg/L, respectively. In this station 67.3% of the sediments are gravel. The data suggest that habitats with high nutrient concentrations, low dissolved oxygen, and low availability of attachment substrata have low densities of this organism.

# Conclusions

- The zoobenthic community densities in Guajataca Reservoir were higher than in La Plata Reservoir, but their diversity, evenness, and richness indexes were similar. This reflects the commonality in the faunal zoobenthos composition of Puerto Rican reservoirs is even across the trophic gradient, but stresses the importance of using invertebrate densities to differentiate mesotrophic (Guajataca) from eutrophic (La Plata) conditions.
- According to Brinkhurst's classification, the zoobenthic community composition and densities of both lakes indicate eutrophic conditions, with moderate pollution and high oxygen demand.
- The benthic communities in the two reservoirs are dominated by the alien snail *Tarebia granifera*. [This species tolerates a wide range of chemical and physical environmental conditions and is the intermediate host for the lung fluke (*Paragonimus westermani*)].
- Several gastropods represent new records for the Island or are new species, reflecting the understudied state of this particular fauna.
- More studies are required to assess the impact of *Tarebia granifera* on native gastropods.
- *Corbicula fluminea* was the most abundant bivalve in the benthic communities of both reservoirs, as compared with *Pisidium casertanum* and *Eupera portoricensis*. The populations of this invasive bivalve probably are reducing the populations of two native bivalves.

- *Corbicula fluminea* populations were composed of small and juvenile individuals (0-13 mm). This suggests high mortality rates of the adults in both lakes and that the species is vulnerable to shifts in water quality, and is not well adapted to tolerate eutrophic conditions.
- This is the first report for *Urnatella gracilis* in Puerto Rico and in the Caribbean region. Entoprocts seem to be numerically important in local reservoirs and are more abundant in areas with hard substrata, high DO, and low TKN concentrations.

# Recommendations

- Conduct further studies related to the ecology, distribution, and abundance of macroinvertebrate communities in other lentic systems of the island.
- Description and taxonomic characterization of the macroinvertebrate fauna in other freshwater systems.
- Assessment of the water quality and its effects on the local benthic taxa under controlled or laboratory conditions.
- Monitor the populations of *C. fluminea*, *P. casertanum* and *E. portoricensis* in the reservoirs and others freshwater systems.
- Assess the impact of introduced snails species, such *T. granifera, P. antipodarum, M. cornuarietis,* and *P. cumingi*, on the native snails populations.

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# Appendices

## Community Analysis

Appendix CA1. Analysis of variance of the abundances of benthic invertebrates in Guajataca Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 43.27623 | 4.80847 | 0.225136 |
| Jan-11 | 9 | 41.12389 | 4.569321 | 0.291134 |
| Feb-11 | 9 | 44.81182 | 4.979091 | 0.123722 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.762645 | 2 | 0.381322 | 1.787468 | ***0.188956*** | 3.402826 |
| Within Groups | 5.119944 | 24 | 0.213331 | | | |
| | | | | | | |
| Total | 5.882588 | 26 | | | | |

Appendix CA2. Analysis of variance of the abundances of benthic invertebrates in Guajataca Reservoir by sampling sites.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 39.66501 | 4.407224 | 0.295244 |
| Transitional | 9 | 46.33687 | 5.148541 | 0.067913 |
| Riverine | 9 | 43.21006 | 4.801118 | 0.062639 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 2.476218 | 2 | 1.238109 | 8.723246 | ***0.001421*** | 3.402826 |
| Within Groups | 3.406371 | 24 | 0.141932 | | | |
| | | | | | | |
| Total | 5.882588 | 26 | | | | |

Appendix CA3. Tukey Kramer Multiple Comparisons of densities means in Guajataca Reservoir by sampling stations.

| Group | Sample Mean | Sample Size |
|---|---|---|
| **Lacustrine** | 4.407224 | 9 |
| **Transitional** | 5.148541 | 9 |
| **Riverine** | 4.801118 | 9 |

| Comparison | Absolute Difference | Std. Error of Difference | Critical Range | Results |
|---|---|---|---|---|
| **Lacustrine to Transitional** | 0.7413169 | 0.125579598 | 0.4433 | **Means are different** |
| **Lacustrine to Riverine** | 0.3938943 | 0.125579598 | 0.4433 | **Means are not different** |
| **Transitional to Riverine** | 0.3474226 | 0.125579598 | 0.4433 | **Means are not different** |

Appendix CA4. Analysis of variance of benthic invertebrates' abundances in lacustrine station of Guajataca Reservoir.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 3 | 13.74659 | 4.582197 | 0.342028 |
| Jan-11 | 3 | 11.90613 | 3.968711 | 0.13693 |
| Feb-11 | 3 | 14.01229 | 4.670763 | 0.263477 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.877085 | 2 | 0.438543 | 1.772045 | ***0.248456*** | 5.143253 |
| Within Groups | 1.484869 | 6 | 0.247478 | | | |
| | | | | | | |
| Total | 2.361954 | 8 | | | | |

Appendix CA5. Analysis of variance of benthic invertebrates' abundances in transitional station of Guajataca Reservoir.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 3 | 15.77478 | 5.258261 | 0.103123 |
| Jan-11 | 3 | 15.04979 | 5.016598 | 0.116042 |
| Feb-11 | 3 | 15.51229 | 5.170763 | 0.007575 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.089824 | 2 | 0.044912 | 0.594229 | ***0.581496*** | 5.143253 |
| Within Groups | 0.45348 | 6 | 0.07558 | | | |
| | | | | | | |
| Total | 0.543304 | 8 | | | | |

Appendix CA6. Analysis of variance of benthic invertebrates' abundance in riverine station of Guajataca Reservoir.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 3 | 13.75485 | 4.584951 | 0.000187 |
| Jan-11 | 3 | 14.16796 | 4.722655 | 0.035115 |
| Feb-11 | 3 | 15.28724 | 5.095748 | 0.005718 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.419074 | 2 | 0.209537 | 15.32478 | ***0.004388*** | 5.143253 |
| Within Groups | 0.082039 | 6 | 0.013673 | | | |
| | | | | | | |
| Total | 0.501113 | 8 | | | | |

Appendix CA7. Tukey Kramer Multiple Comparisons of riverine's means for Guajataca Reservoir.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Dec-10** | 4.584951 | 3 | **December to January** | 0.1377033 | 0.06751073 | 0.293 | **Means are not different** |
| **Jan-11** | 4.722655 | 3 | **December to February** | 0.5107969 | 0.06751073 | 0.293 | **Means are different** |
| **Feb-11** | 5.095748 | 3 | **January to February** | 0.3730936 | 0.06751073 | 0.293 | **Means are different** |

Appendix CA8. Analysis of variance of benthic invertebrates for La Plata Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 41.51509 | 4.612788 | 0.114484 |
| Feb-11 | 9 | 40.31649 | 4.47961 | 0.23166 |
| Mar-11 | 9 | 41.66263 | 4.629181 | 0.112883 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.121129 | 2 | 0.060565 | 0.395823 | ***0.677439*** | 3.402826 |
| Within Groups | 3.672221 | 24 | 0.153009 | | | |
| | | | | | | |
| Total | 3.793351 | 26 | | | | |

Appendix CA9. Analysis of variance of benthic invertebrates for La Plata Reservoir by sampling stations

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 41.60384 | 4.622649 | 0.020261 |
| Transitional | 9 | 43.0139 | 4.779322 | 0.052032 |
| Riverine | 9 | 38.87648 | 4.319608 | 0.278982 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.983149 | 2 | 0.491575 | 4.1982 | ***0.027326*** | 3.402826 |
| Within Groups | 2.810202 | 24 | 0.117092 | | | |
| | | | | | | |
| Total | 3.793351 | 26 | | | | |

Appendix CA10. Tukey Kramer Multiple Comparisons of benthic invertebrates' means for La Plata Reservoir by sampling stations.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 4.622649 | 9 | **Lacustrine to Transitional** | 0.1566729 | 0.114062231 | 0.4026 | **Means are not different** |
| **Transitional** | 4.779322 | 9 | **Lacustrine to Riverine** | 0.3030405 | 0.114062231 | 0.4026 | **Means are not different** |
| **Riverine** | 4.319608 | 9 | **Transitional to Riverine** | 0.4597134 | 0.114062231 | 0.4026 | **Means are different** |

Appendix CA11. Analysis of variance of benthic invertebrates for lacustrine station in La Plata Reservoir by sampling dates

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 3 | 13.88227 | 4.627425 | 0.008942 |
| Feb-11 | 3 | 13.7813 | 4.593765 | 0.032422 |
| Mar-11 | 3 | 13.94027 | 4.646757 | 0.037521 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.004315 | 2 | 0.002157 | 0.082044 | ***0.922247*** | 5.143253 |
| Within Groups | 0.157771 | 6 | 0.026295 | | | |
| | | | | | | |
| Total | 0.162086 | 8 | | | | |

Appendix CA12. Analysis of variance of benthic invertebrates for transitional station in La Plata Reservoir by sampling dates

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 3 | 14.51575 | 4.838582 | 0.049807 |
| Feb-11 | 3 | 13.83555 | 4.611851 | 0.078088 |
| Mar-11 | 3 | 14.6626 | 4.887532 | 0.015334 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.129803 | 2 | 0.064901 | 1.359395 | ***0.325901*** | 5.143253 |
| Within Groups | 0.286457 | 6 | 0.047743 | | | |
| | | | | | | |
| Total | 0.41626 | 8 | | | | |

Appendix CA13. Analysis of variance of benthic invertebrates for riverine station in La Plata Reservoir by sampling dates

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 3 | 13.11707 | 4.372358 | 0.235683 |
| Feb-11 | 3 | 12.69964 | 4.233214 | 0.679286 |
| Mar-11 | 3 | 13.05976 | 4.353254 | 0.183891 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.034135 | 2 | 0.017068 | 0.046597 | ***0.954814*** | 5.143253 |
| Within Groups | 2.19772 | 6 | 0.366287 | | | |
| | | | | | | |
| Total | 2.231856 | 8 | | | | |

Appendix CA14. Analysis of variance of *C. fluminea* abundance in Guajataca Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 27.00092 | 3.000102 | 0.452579 |
| Jan-11 | 9 | 27.67507 | 3.075008 | 0.283616 |
| Feb-11 | 9 | 32.91293 | 3.656992 | 0.17396 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 2.327462 | 2 | 1.163731 | 3.835824 | ***0.03585*** | 3.402826 |
| Within Groups | 7.281237 | 24 | 0.303385 | | | |
| | | | | | | |
| Total | 9.608699 | 26 | | | | |

Appendix CA15. Analysis of variance of *C. fluminea* abundance in Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 27.19336 | 3.021485 | 0.36176 |
| Transitional | 9 | 31.6822 | 3.520245 | 0.403683 |
| Riverine | 9 | 28.71335 | 3.190373 | 0.290857 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.158301 | 2 | 0.579151 | 1.644848 | ***0.214067*** | 3.402826 |
| Within Groups | 8.450398 | 24 | 0.3521 | | | |
| | | | | | | |
| Total | 9.608699 | 26 | | | | |

Appendix CA16. Tukey Kramer Multiple Comparisons of *C. fluminea* mean for Guajataca Reservoir by sampling dates.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Dec-10** | 3.000102 | 9 | **December to January** | 0.0749061 | 0.183601287 | 0.6481 | **Means are not different** |
| **Jan-11** | 3.075008 | 9 | **December to February** | 0.65689 | 0.183601287 | 0.6481 | **Means are different** |
| **Feb-11** | 3.656992 | 9 | **January to February** | 0.5819839 | 0.183601287 | 0.6481 | **Means are not different** |

Appendix CA17. Analysis of variance of *C. fluminea* class I in sampling dates for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 26.65438 | 2.961598 | 0.45901 |
| Jan-11 | 9 | 27.41893 | 3.046548 | 0.2699 |
| Feb-11 | 9 | 32.40962 | 3.601069 | 0.206101 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 2.170899 | 2 | 1.08545 | 3.482686 | 0.046991 | 3.402826 |
| Within Groups | 7.480086 | 24 | 0.31167 | | | |
| | | | | | | |
| Total | 9.650985 | 26 | | | | |

Appendix CA18. Analysis of variance of *C. fluminea* class II in sampling dates for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 1.47993 | 0.164437 | 0.867084 |
| Jan-11 | 9 | -2.70927 | -0.30103 | 0 |
| Feb-11 | 9 | 4.96284 | 0.551427 | 1.143172 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 3.279308 | 2 | 1.639654 | 2.446934 | 0.107862 | 3.402826 |
| Within Groups | 16.08204 | 24 | 0.670085 | | | |
| | | | | | | |
| Total | 19.36135 | 26 | | | | |

Appendix CA19. Analysis of variance of *C. fluminea* class III in sampling dates for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 4.736113 | 0.526235 | 1.049699 |
| Jan-11 | 9 | 5.535911 | 0.615101 | 1.902601 |
| Feb-11 | 9 | 4.459577 | 0.495509 | 1.43013 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.069431 | 2 | 0.034716 | 0.023765 | 0.976538 | 3.402826 |
| Within Groups | 35.05944 | 24 | 1.46081 | | | |
| | | | | | | |
| Total | 35.12887 | 26 | | | | |

Appendix CA20. Analysis of variance of *C. fluminea* class IV in sampling dates for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 6.892177 | 0.765797 | 1.120303 |
| Jan-11 | 9 | 6.610357 | 0.734484 | 1.657894 |
| Feb-11 | 9 | 9.011377 | 1.001264 | 1.898634 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.38279 | 2 | 0.191395 | 0.122772 | 0.885017 | 3.402826 |
| Within Groups | 37.41464 | 24 | 1.558943 | | | |
| | | | | | | |
| Total | 37.79743 | 26 | | | | |

Appendix CA21. Analysis of variance of *C. fluminea* class I in stations for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 27.12287 | 3.013652 | 0.354465 |
| Transitional | 9 | 31.33919 | 3.482133 | 0.419372 |
| Riverine | 9 | 28.02086 | 3.113429 | 0.295521 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.096114 | 2 | 0.548057 | 1.53753 | 0.235343 | 3.402826 |
| Within Groups | 8.554871 | 24 | 0.356453 | | | |
| | | | | | | |
| Total | 9.650985 | 26 | | | | |

Appendix CA22. Analysis of variance of *C. fluminea* class II in stations for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 0.299545 | 0.033283 | 0.453382 |
| Transitional | 9 | 1.654009 | 0.183779 | 0.931056 |
| Riverine | 9 | 1.779945 | 0.197772 | 1.017018 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.149704 | 2 | 0.074852 | 0.093508 | 0.91106 | 3.402826 |
| Within Groups | 19.21165 | 24 | 0.800485 | | | |
| | | | | | | |
| Total | 19.36135 | 26 | | | | |

Appendix CA23. Analysis of variance of *C. fluminea* class III in stations for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 0.895569 | 0.099508 | 0.701582 |
| Transitional | 9 | 9.674127 | 1.074903 | 1.796171 |
| Riverine | 9 | 4.161904 | 0.462434 | 1.34652 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 4.37469 | 2 | 2.187345 | 1.706964 | 0.202712 | 3.402826 |
| Within Groups | 30.75418 | 24 | 1.281424 | | | |
| | | | | | | |
| Total | 35.12887 | 26 | | | | |

Appendix CA24. Analysis of variance of *C. fluminea* class IV in stations for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 6.501142 | 0.722349 | 1.213228 |
| Transitional | 9 | 8.069075 | 0.896564 | 1.364596 |
| Riverine | 9 | 7.943693 | 0.882633 | 2.125767 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.168707 | 2 | 0.084353 | 0.053802 | 0.947734 | 3.402826 |
| Within Groups | 37.62873 | 24 | 1.567864 | | | |
| | | | | | | |
| Total | 37.79743 | 26 | | | | |

Appendix CA25. Analysis of variance of *C. fluminea* abundance in La Plata Reservoir by sampling dates

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 22.99998 | 2.555554 | 0.875933 |
| Jan-11 | 9 | 15.41286 | 1.71254 | 1.809072 |
| Feb-11 | 9 | 23.362 | 2.595777 | 0.812212 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 4.477199 | 2 | 2.2386 | 1.920326 | ***0.168415*** | 3.402826 |
| Within Groups | 27.97774 | 24 | 1.165739 | | | |
| | | | | | | |
| Total | 32.45494 | 26 | | | | |

Appendix CA26. Analysis of variance of *C. fluminea* abundance in La Plata Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 15.52949 | 1.725499 | 0.863186 |
| Transitional | 9 | 26.70476 | 2.967195 | 0.440847 |
| Riverine | 9 | 19.54059 | 2.171177 | 1.862553 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 7.122251 | 2 | 3.561126 | 3.373784 | ***0.051145*** | 3.402826 |
| Within Groups | 25.33269 | 24 | 1.055529 | | | |
| | | | | | | |
| Total | 32.45494 | 26 | | | | |

Appendix CA27. Tukey Kramer Multiple Comparisons of *C. fluminea* means for La Plata Reservoirs.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 1.758947 | 9 | **Lacustrine to Transitional** | 1.2082485 | 0.324788244 | 1.1465 | **Means are different** |
| **Transitional** | 2.967195 | 9 | **Lacustrine to Riverine** | 0.4456777 | 0.324788244 | 1.1465 | **Means are not different** |
| **Riverine** | 2.204624 | 9 | **Transitional to Riverine** | 0.7625707 | 0.324788244 | 1.1465 | **Means are not different** |

Appendix CA28. Analysis of variance of *C. fluminea* class I in sampling dates for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 15.96771 | 1.77419 | 1.696308 |
| Feb-11 | 9 | 15.25503 | 1.695004 | 1.629442 |
| Mar-11 | 9 | 23.15695 | 2.572995 | 0.787448 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 4.245683 | 2 | 2.122842 | 1.548315 | 0.233105 | 3.402826 |
| Within Groups | 32.90558 | 24 | 1.371066 | | | |
| | | | | | | |
| Total | 37.15127 | 26 | | | | |

Appendix CA29. Analysis of variance of *C. fluminea* class II in sampling dates for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | -1.14626 | -0.12736 | 0.271443 |
| Feb-11 | 9 | 0 | 0 | 0 |
| Mar-11 | 9 | 0.299545 | 0.033283 | 0.453382 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.129408 | 2 | 0.064704 | 0.267805 | 0.767313 | 3.402826 |
| Within Groups | 5.7986 | 24 | 0.241608 | | | |
| | | | | | | |
| Total | 5.928008 | 26 | | | | |

Appendix CA30. Analysis of variance of *C. fluminea* class III in sampling dates for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | -1.43557 | -0.15951 | 0.180256 |
| Feb-11 | 9 | 2.868179 | 0.318687 | 0.399897 |
| Mar-11 | 9 | 0.085427 | 0.009492 | 0.867815 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.058498 | 2 | 0.529249 | 1.096535 | 0.350185 | 3.402826 |
| Within Groups | 11.58374 | 24 | 0.482656 | | | |
| | | | | | | |
| Total | 12.64224 | 26 | | | | |

Appendix CA31. Analysis of variance of *C. fluminea* class IV in sampling dates for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 0.711792 | 0.079088 | 0.574369 |
| Feb-11 | 9 | 1.753716 | 0.194857 | 1.029845 |
| Mar-11 | 9 | 3.690093 | 0.41001 | 1.28285 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.507609 | 2 | 0.253804 | 0.263733 | 0.770376 | 3.402826 |
| Within Groups | 23.09651 | 24 | 0.962355 | | | |
| | | | | | | |
| Total | 23.60412 | 26 | | | | |

Appendix CA32. Analysis of variance of *C. fluminea* class I in stations for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 16.86123 | 1.87347 | 1.009977 |
| Transitional | 9 | 20.73862 | 2.304291 | 1.510568 |
| Riverine | 9 | 16.47882 | 1.83098 | 2.131556 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.234307 | 2 | 0.617153 | 0.397984 | 0.676024 | 3.402826 |
| Within Groups | 37.21681 | 24 | 1.5507 | | | |
| | | | | | | |
| Total | 38.45112 | 26 | | | | |

Appendix CA33. Analysis of variance of *C. fluminea* class II in stations for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | -1.14626 | -0.12736 | 0.271443 |
| Transitional | 9 | -2.70927 | -0.30103 | 0 |
| Riverine | 9 | 0.299545 | 0.033283 | 0.453382 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.503197 | 2 | 0.251599 | 1.041349 | 0.368387 | 3.402826 |
| Within Groups | 5.7986 | 24 | 0.241608 | | | |
| | | | | | | |
| Total | 6.301797 | 26 | | | | |

Appendix CA34. Analysis of variance of *C. fluminea* class III in stations for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | -0.97415 | -0.10824 | 0.334516 |
| Transitional | 9 | 1.820547 | 0.202283 | 1.067632 |
| Riverine | 9 | -1.43557 | -0.15951 | 0.180256 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.689836 | 2 | 0.344918 | 0.653913 | 0.529026 | 3.402826 |
| Within Groups | 12.65923 | 24 | 0.527468 | | | |
| | | | | | | |
| Total | 13.34906 | 26 | | | | |

Appendix CA35. Analysis of variance of *C. fluminea* class IV in stations for La Plata Reservoir

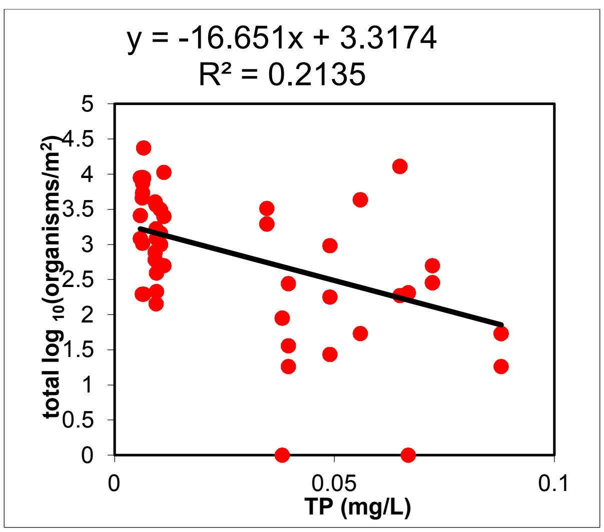
SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 1.581603 | 0.175734 | 0.979814 |
| Transitional | 9 | 4.151517 | 0.46128 | 1.371413 |
| Riverine | 9 | 0.422481 | 0.046942 | 0.498114 |

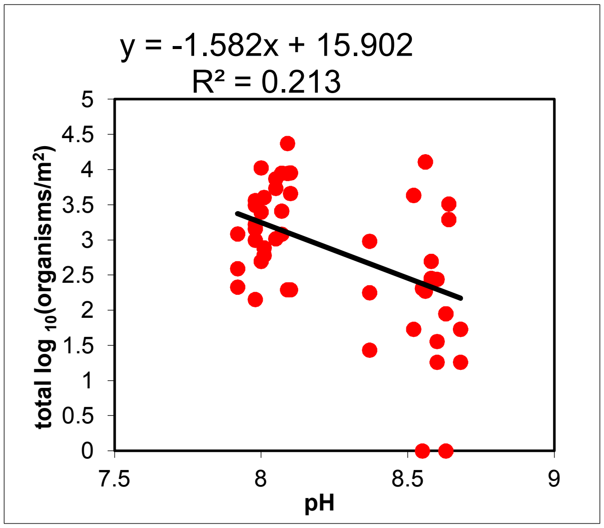
ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.809397 | 2 | 0.404699 | 0.426097 | 0.657897 | 3.402826 |
| Within Groups | 22.79472 | 24 | 0.94978 | | | |
| | | | | | | |
| Total | 23.60412 | 26 | | | | |

Appendix CA36. Correlation between *C. fluminea* and TP concentrations.



Appendix CA37. Correlation between *C. fluminea* and pH values.




Appendix CA38. Analysis of variance of *T. granifera* abundance in Guajataca Reservoir by sampling dates

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 41.80922 | 4.645469 | 0.302707 |
| Jan-11 | 9 | 40.02073 | 4.446748 | 0.282105 |
| Feb-11 | 9 | 43.27953 | 4.808836 | 0.247837 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.591861 | 2 | 0.29593 | 1.066225 | ***0.360059*** | 3.402826 |
| Within Groups | 6.661196 | 24 | 0.27755 | | | |
| | | | | | | |
| Total | 7.253057 | 26 | | | | |

Appendix CA39. Analysis of variance of *T. granifera* abundance in Guajataca Reservoir by sampling stations

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 38.16238 | 4.240265 | 0.338414 |
| Transitional | 9 | 45.48585 | 5.053983 | 0.072175 |
| Riverine | 9 | 41.46124 | 4.606805 | 0.122371 |

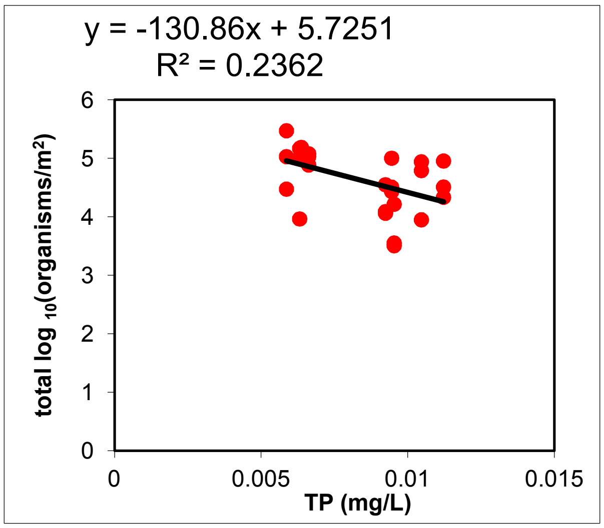
ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 2.989376 | 2 | 1.494688 | 8.413506 | ***0.001703*** | 3.402826 |
| Within Groups | 4.263681 | 24 | 0.177653 | | | |
| | | | | | | |
| Total | 7.253057 | 26 | | | | |

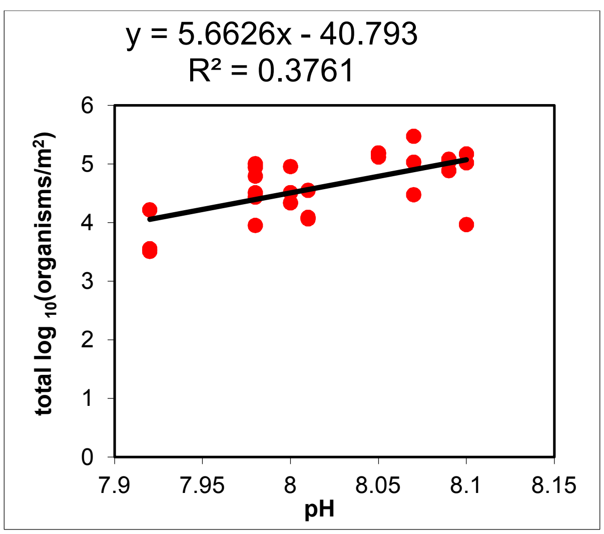
Appendix CA40. Tukey Kramer Multiple Comparisons of *T. granifera* means for Guajataca Reservoir

| Group | Sample Mean | Sample Size | Comparison | Absolute Difference | Std. Error of Difference | Critical Range | Results |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 4.240265 | 9 | **Lacustrine to Transitional** | 0.8137187 | 0.140496491 | 0.496 | **Means are different** |
| **Transitional** | 5.053983 | 9 | **Lacustrine to Riverine** | 0.3665401 | 0.140496491 | 0.496 | **Means are not different** |
| **Riverine** | 4.606805 | 9 | **Transitional to Riverine** | 0.4471786 | 0.140496491 | 0.496 | **Means are not different** |

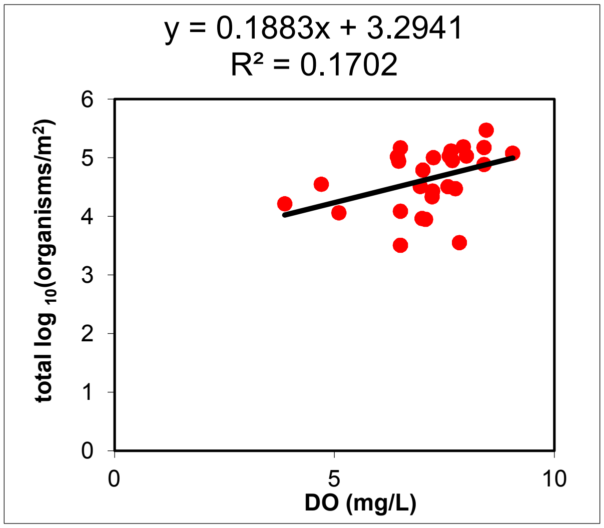
Appendix CA41. Correlations between *T. granifera* densities an TP concentrations.




Appendix CA42. Correlations between *T. granifera* and pH values.



Appendix CA43. Correlations between *T. granifera* and DO concentrations.




Appendix CA44. Analysis of variance of *T. granifera* abundance in La Plata Reservoir by sampling dates

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 38.16817 | 4.240908 | 0.320423 |
| Feb-11 | 9 | 32.5476 | 3.6164 | 0.3859 |
| Mar-11 | 9 | 39.01419 | 4.33491 | 0.326198 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 2.745307 | 2 | 1.372654 | 3.988261 | ***0.031957*** | 3.402826 |
| Within Groups | 8.260163 | 24 | 0.344173 | | | |
| | | | | | | |
| Total | 11.00547 | 26 | | | | |

Appendix CA45. Tukey Kramer Multiple Comparisons of *T. granifera* means for La Plata Reservoir by sampling dates.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Jan-11** | 4.240908 | 9 | **January to February** | 0.6245078 | 0.195554334 | 0.6903 | **Means are not different** |
| **Feb-11** | 3.6164 | 9 | **January to March** | 0.0940018 | 0.195554334 | 0.6903 | **Means are not different** |
| **Mar-11** | 4.33491 | 9 | **February to March** | 0.7185096 | 0.195554334 | 0.6903 | **Means are different** |

Appendix CA46. Analysis of variance of *T. granifera* abundance in La Plata Reservoir by sampling stations

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 36.58275 | 4.06475 | 0.370728 |
| Transitional | 9 | 40.65926 | 4.517695 | 0.164968 |
| Riverine | 9 | 32.48795 | 3.609772 | 0.376305 |

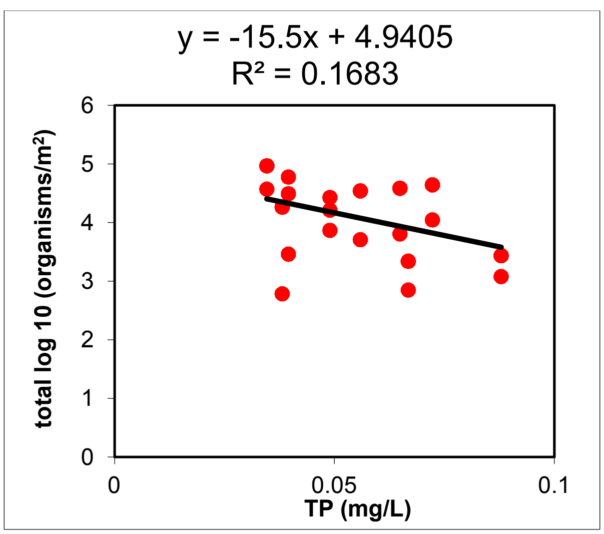
ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 3.709463 | 2 | 1.854731 | 6.101084 | ***0.007206*** | 3.402826 |
| Within Groups | 7.296008 | 24 | 0.304 | | | |
| | | | | | | |
| Total | 11.00547 | 26 | | | | |

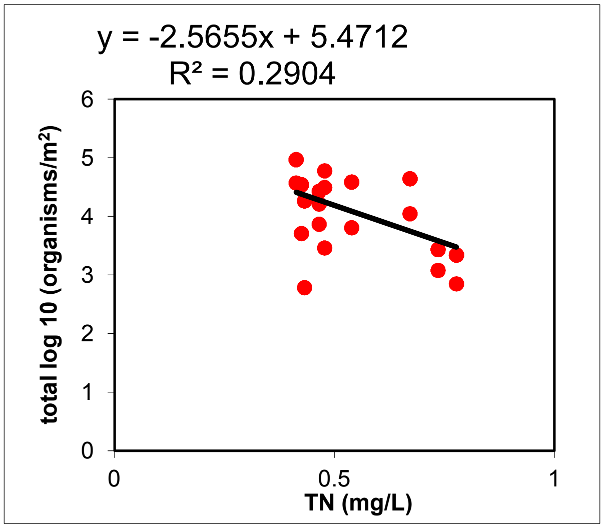
Appendix CA47. Tukey Kramer Multiple Comparisons of *T. granifera* means for La Plata Reservoir by sampling stations.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 4.06475 | 9 | **Lacustrine to Transitional** | 0.4529455 | 0.183787413 | 0.6488 | **Means are not differe** |
| **Transitional** | 4.517695 | 9 | **Lacustrine to Riverine** | 0.4549772 | 0.183787413 | 0.6488 | **Means are not differe** |
| **Riverine** | 3.609772 | 9 | **Transitional to Riverine** | 0.9079227 | 0.183787413 | 0.6488 | **Means are different** |

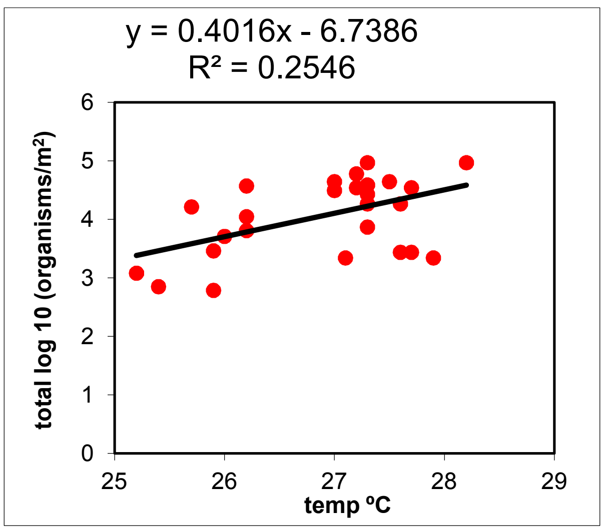
Appendix CA48.Correlations with TP concentrations, La Plata Reservoir



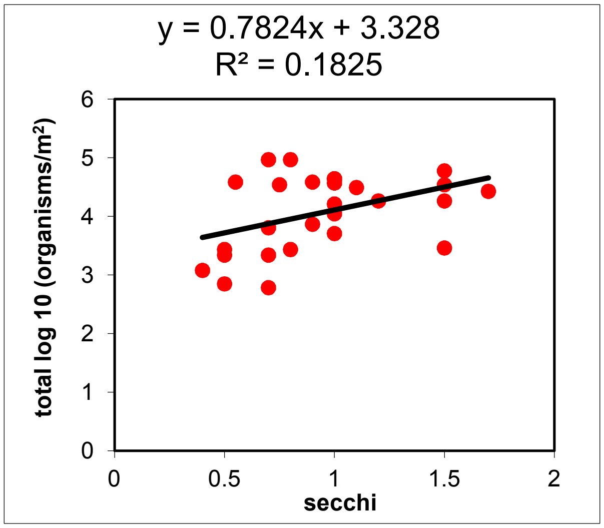
Appendix CA49. Correlations with TKN concentrations, La Plata Reservoir.




Appendix CA50. Correlations with temperatures, La Plata Reservoir



Appendix CA51. Correlations with secchi depth values, La Plata Reservoir.




Appendix CA52. Analysis of variance of Complex *Pyrgophorus/Potamopyrgus* abundance for Guajataca Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 30.71449 | 3.412721 | 0.418001 |
| Jan-11 | 9 | 28.00688 | 3.111875 | 0.518651 |
| Feb-11 | 9 | 30.17735 | 3.353039 | 0.299865 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.45669 | 2 | 0.228345 | 0.554004 | ***0.581819*** | 3.402826 |
| Within Groups | 9.892143 | 24 | 0.412173 | | | |
| | | | | | | |
| Total | 10.34883 | 26 | | | | |

Appendix CA53. Analysis of variance of *Pyrgophorus/Potamopyrgus* Complex abundance for Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 25.09238 | 2.788042 | 0.465376 |
| Transitional | 9 | 33.46833 | 3.718704 | 0.116398 |
| Riverine | 9 | 30.33801 | 3.37089 | 0.214275 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 3.980448 | 2 | 1.990224 | 7.50039 | ***0.002949*** | 3.402826 |
| Within Groups | 6.368385 | 24 | 0.265349 | | | |
| | | | | | | |
| Total | 10.34883 | 26 | | | | |

Appendix CA54.Tukey Kramer Multiple Comparisons of Complex *Pyrgophorus/Potamopyrgus* for Guajataca Reservoir by sampling stations.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 4.06475 | 9 | **Lacustrine to Transitional** | 0.4529455 | 0.183787413 | 0.6488 | **Means are not different** |
| **Transitional** | 4.517695 | 9 | **Lacustrine to Riverine** | 0.4549772 | 0.183787413 | 0.6488 | **Means are not different** |
| **Riverine** | 3.609772 | 9 | **Transitional to Riverine** | 0.9079227 | 0.183787413 | 0.6488 | **Means are different** |

Appendix CA55. Analysis of variance of Complex *Pyrgophorus/Potamopyrgus* abundance for La Plata Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 24.23828 | 2.693142 | 0.314209 |
| Feb-11 | 9 | 20.89282 | 2.321424 | 0.400687 |
| Mar-11 | 9 | 23.51741 | 2.613045 | 0.369459 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.688896 | 2 | 0.344448 | 0.952957 | **0.399712** | 3.402826 |
| Within Groups | 8.674834 | 24 | 0.361451 | | | |
| | | | | | | |
| Total | 9.36373 | 26 | | | | |

Appendix CA56. Analysis of variance of *Pyrgophorus/Potamopyrgus* Complex abundance for La Plata Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 19.7939 | 2.199323 | 0.353247 |
| Transitional | 9 | 27.15592 | 3.017325 | 0.187927 |
| Riverine | 9 | 21.69868 | 2.410964 | 0.223694 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 3.244778 | 2 | 1.622389 | 6.3634 | ***0.006064*** | 3.402826 |
| Within Groups | 6.118952 | 24 | 0.254956 | | | |
| | | | | | | |
| Total | 9.36373 | 26 | | | | |

Appendix CA57.Tukey Kramer Multiple Comparisons of *Pyrgophorus/Potamopyrgus* Complex for La Plata Reservoir by sampling stations.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 2.199323 | 9 | **Lacustrine to Transitional** | 0.818002 | 0.168310667 | 0.5941 | **Means are different** |
| **Transitional** | 3.017325 | 9 | **Lacustrine to Riverine** | 0.2116414 | 0.168310667 | 0.5941 | **Means are not different** |
| **Riverine** | 2.410964 | 9 | **Transitional to Riverine** | 0.6063607 | 0.168310667 | 0.5941 | **Means are different** |

Appendix CA58. Analysis of variance of *U. gracilis* abundance in Guajataca Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 33.23752 | 3.693058 | 0.369701 |
| Jan-11 | 9 | 31.03629 | 3.448476 | 0.913199 |
| Feb-11 | 9 | 35.82521 | 3.980579 | 0.104751 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.276863 | 2 | 0.638432 | 1.380242 | ***0.270774*** | 3.402826 |
| Within Groups | 11.10122 | 24 | 0.462551 | | | |
| | | | | | | |
| Total | 12.37808 | 26 | | | | |

Appendix CA59. Analysis of variance of *U. gracilis* abundance in Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 28.90448 | 3.211609 | 0.846566 |
| Transitional | 9 | 35.47305 | 3.94145 | 0.155078 |
| Riverine | 9 | 35.72149 | 3.969054 | 0.130433 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 3.321459 | 2 | 1.66073 | 4.400926 | ***0.023537*** | 3.402826 |
| Within Groups | 9.05662 | 24 | 0.377359 | | | |
| | | | | | | |
| Total | 12.37808 | 26 | | | | |

Appendix CA60. Tukey Kramer Multiple Comparisons of *U. gracilis* means for Guajataca Reservoir by sampling stations.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 3.211609 | 9 | **Lacustrine to Transitional** | 0.7298406 | 0.204765223 | 0.7228 | **Means are different** |
| **Transitional** | 3.94145 | 9 | **Lacustrine to Riverine** | 0.7574455 | 0.204765223 | 0.7228 | **Means are different** |
| **Riverine** | 3.969054 | 9 | **Transitional to Riverine** | 0.0276049 | 0.204765223 | 0.7228 | **Means are not different** |

Appendix CA61 Analysis of variance of *U. gracilis* abundance in La Plata Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 35.21338 | 3.912598 | 0.298287 |
| Feb-11 | 9 | 30.15292 | 3.350324 | 4.418779 |
| Mar-11 | 9 | 32.59335 | 3.621484 | 0.499566 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.42328 | 2 | 0.71164 | 0.409253 | ***0.668694*** | 3.402826 |
| Within Groups | 41.73306 | 24 | 1.738877 | | | |
| | | | | | | |
| Total | 43.15634 | 26 | | | | |

Appendix CA62. Analysis of variance of *U. gracilis* abundance in La Plata Reservoir by sampling stations.

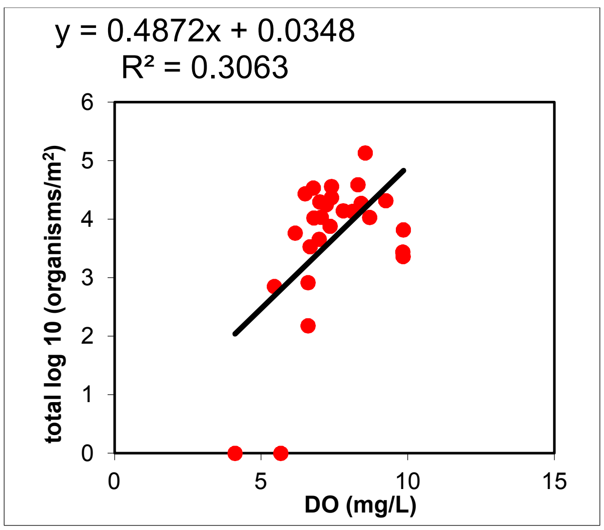
SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 36.23037 | 4.025597 | 0.577351 |
| Transitional | 9 | 35.10395 | 3.900439 | 0.269942 |
| Riverine | 9 | 26.62533 | 2.95837 | 3.781449 |

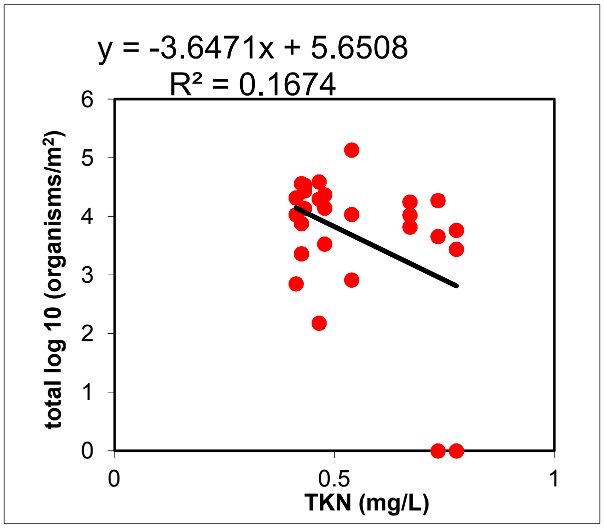
ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 6.1264 | 2 | 3.0632 | 1.985334 | ***0.159258*** | 3.402826 |
| Within Groups | 37.02994 | 24 | 1.542914 | | | |
| | | | | | | |
| Total | 43.15634 | 26 | | | | |

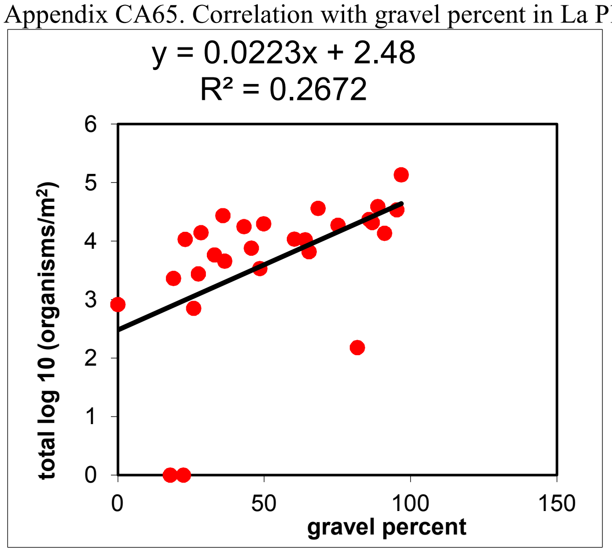
Appendix CA63. Correlation with DO concentrations in La Plata Reservoir.



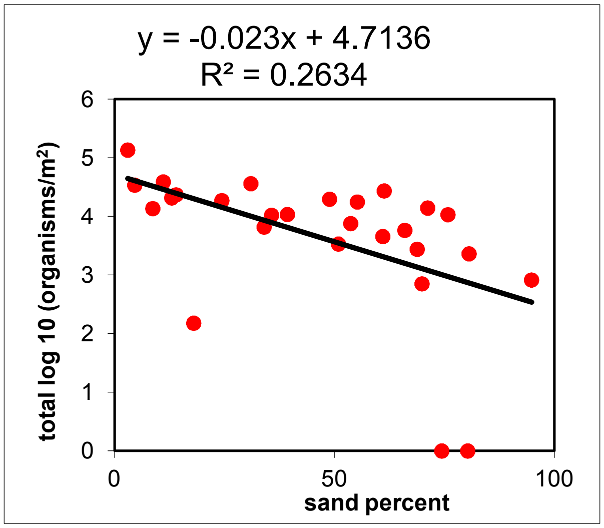
Appendix CA64. Correlations with TKN concentrations in La Plata Reservoir



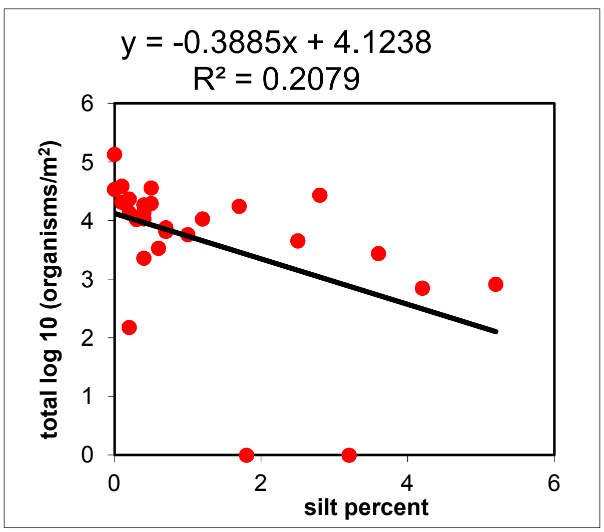

Appendix CA65. Correlation with gravel percent in La Plata Reservoir. .



Appendix CA66. Correlation with sand percent in La Plata Reservoir.




ppendix CA67. Correlation with silt percent in La Plata Reservoir.



## Diversity Indices

Appendix DI1. Analisis of variances of species diversity values for benthic invertebrates of Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 57.89529 | 19.29843 | 13.796 |
| Transitional | 3 | 102.1276 | 34.04254 | 88.69131 |
| Riverine | 3 | 73.41383 | 24.47128 | 7.975595 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 335.7562 | 2 | 167.8781 | 4.559307 | 0.062505 | 5.143253 |
| Within Groups | 220.9258 | 6 | 36.82097 | | | |
| | | | | | | |
| Total | 556.682 | 8 | | | | |

Appendix DI2: Analisis of variances of species diversity values for benthic invertebrates of La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 109.8544 | 36.61812 | 61.28458 |
| Transitional | 3 | 71.1574 | 23.71913 | 81.29025 |
| Riverine | 3 | 61.25214 | 20.41738 | 0 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 439.7493 | 2 | 219.8746 | 4.62651 | 0.060868 | 5.143253 |
| Within Groups | 285.1497 | 6 | 47.52494 | | | |
| | | | | | | |
| Total | 724.8989 | 8 | | | | |

Appendix DI3. Analysis of variance of species richness for benthic macroinvertebrates community of Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 5.165777 | 1.721926 | 0.001034 |
| Transitional | 3 | 4.815406 | 1.605135 | 0.031913 |
| Riverine | 3 | 5.153148 | 1.717716 | 0.019429 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.026332 | 2 | 0.013166 | 0.754127 | ***0.510313*** | 5.143253 |
| Within Groups | 0.104752 | 6 | 0.017459 | | | |
| | | | | | | |
| Total | 0.131084 | 8 | | | | |

Appendix DI4. Analysis of variance of richness values for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 4.552908 | 1.517636 | 0.05039 |
| Transitional | 3 | 4.09391 | 1.364637 | 0.006005 |
| Riverine | 3 | 5.767985 | 1.922662 | 0.077135 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.498846 | 2 | 0.249423 | 5.603769 | ***0.042393*** | 5.143253 |
| Within Groups | 0.267059 | 6 | 0.04451 | | | |
| | | | | | | |
| Total | 0.765906 | 8 | | | | |

Appendix DI5. Tukey Kramer Multiple Comparisons for richness values in La Plata Reservoir

| Group | Sample Mean | Sample Size | Comparison | Absolute Difference | Std. Error of Difference | Critical Range | Results |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 1.517636 | 3 | **Lacustrine to Transitional** | 0.1529995 | 0.121805712 | 0.5286 | **Means are not different** |
| **Transitional** | 1.364637 | 3 | **Lacustrine to riverine** | 0.4050254 | 0.121805712 | 0.5286 | **Means are not different** |
| **Riverine** | 1.922662 | 3 | **Transitional to Riverine** | 0.558025 | 0.121805712 | 0.5286 | **Means are different** |

Appendix DI6. Analysis of variance of evenness values for Guajataca Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 0.959815 | 0.319938 | 0.000203 |
| Transitional | 3 | 1.133921 | 0.377974 | 0.001333 |
| Riverine | 3 | 1.025867 | 0.341956 | 1.8E-06 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.00515 | 2 | 0.002575 | 5.023983 | ***0.052263*** | 5.143253 |
| Within Groups | 0.003075 | 6 | 0.000513 | | | |
| | | | | | | |
| Total | 0.008226 | 8 | | | | |

Appendix DI7. Tukey Kramer Multiple Comparisons of eveness values for Guajataca Reservoir

| Group | Sample Mean | Sample Size | Comparison | Absolute Difference | Std. Error of Difference | Critical Range | Results |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 0.319938 | 3 | **Lacustrine to Transitional** | 0.0580354 | 0.013071065 | 0.0567 | **Means are different** |
| **Transitional** | 0.377974 | 3 | **Lacustrine to Riverine** | 0.0220173 | 0.013071065 | 0.0567 | **Means are not different** |
| **Riverine** | 0.341956 | 3 | **Transitional to Riverine** | 0.036018 | 0.013071065 | 0.0567 | **Means are not different** |

Appendix DI8. Analysis of variance of evenness values for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 1.189551 | 0.396517 | 4.73E-05 |
| Transitional | 3 | 1.107742 | 0.369247 | 0.001304 |
| Riverine | 3 | 0.957845 | 0.319282 | 0.000201 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.009206 | 2 | 0.004603 | 8.894139 | ***0.016046*** | 5.143253 |
| Within Groups | 0.003105 | 6 | 0.000518 | | | |
| | | | | | | |
| Total | 0.012311 | 8 | | | | |

Appendix DI9. Tukey Kramer Multiple Comparisons of evenness means for La Plata Reservoir.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 0.396517 | 3 | **Lacustrine to Transitional** | 0.0272697 | 0.013133997 | 0.057 | **Means are not different** |
| **Transitional** | 0.369247 | 3 | **Lacustrine to Riverine** | 0.0772355 | 0.013133997 | 0.057 | **Means are different** |
| **Riverine** | 0.319282 | 3 | **Transitional to Riverine** | 0.0499658 | 0.013133997 | 0.057 | **Means are not different** |

## Physiochemical parameters

Appendix PP1. Analysis of variance of temperatures in Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 233.6 | 25.95556 | 0.035278 |
| Transitional | 9 | 235.8 | 26.2 | 0.0675 |
| Riverine | 9 | 238.2 | 26.46667 | 0.1 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.176296 | 2 | 0.588148 | 8.70137 | ***0.001439*** | 3.402826 |
| Within Groups | 1.622222 | 24 | 0.067593 | | | |
| | | | | | | |
| Total | 2.798519 | 26 | | | | |

Appendix PP2. Analysis of variance of temperatures in Guajataca Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 234.7 | 26.07778 | 0.069444 |
| Jan-11 | 9 | 236.1 | 26.23333 | 0.195 |
| Feb-11 | 9 | 236.8 | 26.31111 | 0.053611 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.254074 | 2 | 0.127037 | 1.198253 | ***0.319137*** | 3.402826 |
| Within Groups | 2.544444 | 24 | 0.106019 | | | |
| | | | | | | |
| Total | 2.798519 | 26 | | | | |

Appendix PP3. Tukey Kramer Multiple Comparisons of temperatures means for Guajataca Reservoir.

| **Group** | **Sample Mean** | **Sample Size** |
|---|---|---|
| **Lacustrine** | 25.95556 | 9 |
| **Transitional** | 26.2 | 9 |
| **Riverine** | 26.46667 | 9 |

| **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|
| **Lacustrine to Transitional** | 0.2444444 | 0.086661918 | 0.3059 | **Means are not different** |
| **Lacustrine to Riverine** | 0.5111111 | 0.086661918 | 0.3059 | **Means are different** |
| **Transitional to Riverine** | 0.2666667 | 0.086661918 | 0.3059 | **Means are not different** |

Appendix PP4. Analysis of variance of temperatures by sampling stations at La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 241.2 | 26.8 | 0.5525 |
| Transitional | 9 | 243.3 | 27.03333 | 0.5725 |
| Riverine | 9 | 241.7 | 26.85556 | 1.012778 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.267407 | 2 | 0.133704 | 0.18763 | ***0.830126*** | 3.402826105 |
| Within Groups | 17.10222 | 24 | 0.712593 | | | |
| | | | | | | |
| Total | 17.36963 | 26 | | | | |

Appendix PP5. Analysis of variance of temperatures by sampling dates for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 245.2 | 27.24444 | 0.045278 |
| Feb-11 | 9 | 232.7 | 25.85556 | 0.130278 |
| Mar-11 | 9 | 248.3 | 27.58889 | 0.101111 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 15.1563 | 2 | 7.578148 | 82.17269 | ***1.83263E-11*** | 3.402826 |
| Within Groups | 2.213333 | 24 | 0.092222 | | | |
| | | | | | | |
| Total | 17.36963 | 26 | | | | |

Appendix PP6. Tukey Kramer Multiple Comparisons of temperature means for La Plata Reservoir by sampling dates

| **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|
| 27.24444 | 9 | **January to February** | 1.3888889 | 0.10122704 | 0.3573 | **Means are different** |
| 25.85556 | 9 | **January to March** | 0.3444444 | 0.10122704 | 0.3573 | **Means are not different** |
| 27.58889 | 9 | **February to March** | 1.7333333 | 0.10122704 | 0.3573 | **Means are different** |

Appendix PP7. Analysis of variance of dissolved oxygen in Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 62.59 | 6.954444 | 2.506303 |
| Transitional | 9 | 64.86 | 7.206667 | 0.324825 |
| Riverine | 9 | 64.67 | 7.185556 | 1.478028 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.352422 | 2 | 0.176211 | 0.122677 | ***0.885101*** | 3.402826105 |
| Within Groups | 34.47324 | 24 | 1.436385 | | | |
| | | | | | | |
| Total | 34.82567 | 26 | | | | |

Appendix PP8. Analysis of variance of dissolved oxygen in Guajataca Reservoir by sampling dates.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 54.43 | 6.047778 | 1.539619 |
| Jan-11 | 9 | 73.24 | 8.137778 | 0.224519 |
| Feb-11 | 9 | 64.45 | 7.161111 | 0.128511 |

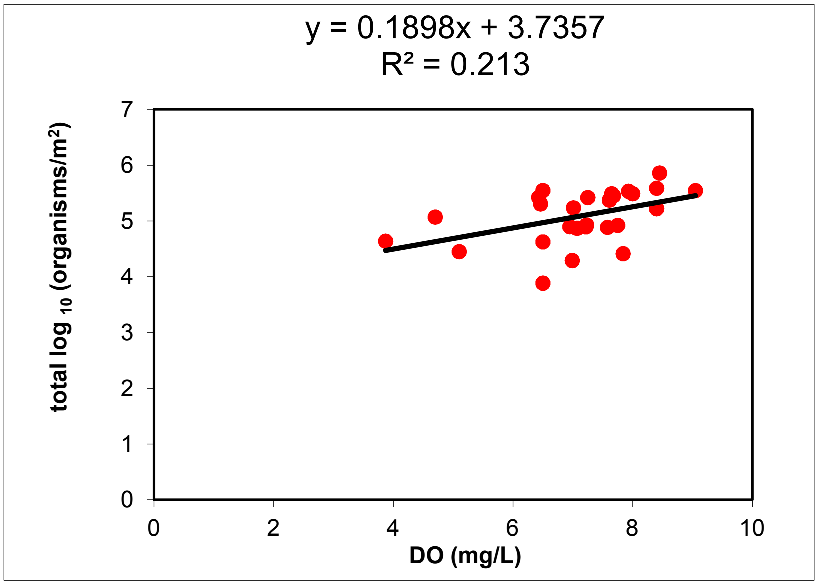
ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 19.68447 | 2 | 9.842233 | 15.60072 | ***4.56174E-05*** | 3.402826 |
| Within Groups | 15.1412 | 24 | 0.630883 | | | |
| | | | | | | |
| Total | 34.82567 | 26 | | | | |

Appendix PP9. Tukey Kramer Multiple Comparisons of dissolved oxygen concentration means for Guajataca reservoir by sampling dates.

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Dec-10** | 6.047778 | 9 | **December to January** | 2.09 | 0.346525969 | 1.5039 | **Means are different** |
| **Jan-11** | 8.137778 | 9 | **December to February** | 1.1377778 | 0.346525969 | 1.5039 | **Means are not different** |
| **Feb-11** | 7.185556 | 9 | **January to February** | 0.9522222 | 0.346525969 | 1.5039 | **Means are not different** |

Appendix PP10. Correlation with DO concentrations, Guajataca Reservoir.




Appendix PP11.Analysis of variance of dissolved oxygen by sampling stations for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 65.16 | 7.24 | 0.471375 |
| Transitional | 9 | 71.86 | 7.984444 | 2.273978 |
| Riverine | 9 | 63.36 | 7.04 | 2.921825 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 4.458519 | 2 | 2.229259 | 1.18009 | ***0.324455*** | 3.402826 |
| Within Groups | 45.33742 | 24 | 1.889059 | | | |
| | | | | | | |
| Total | 49.79594 | 26 | | | | |

Appendix PP12. Analysis of variance of dissolved oxygen by sampling dates for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 74.94 | 8.326667 | 1.38085 |
| Feb-11 | 9 | 65.46 | 7.273333 | 2.904 |
| Mar-11 | 9 | 59.98 | 6.664444 | 0.348428 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 12.72972 | 2 | 6.364859 | 4.121181 | ***0.028934*** | 3.402826 |
| Within Groups | 37.06622 | 24 | 1.544426 | | | |
| | | | | | | |
| Total | 49.79594 | 26 | | | | |

Appendix PP13. Tukey Kramer Multiple Comparisons of dissolved oxygen means for La Plata Reservoir by sampling dates

| **Group** | **Sample Mean** | **Sample Size** |
|---|---|---|
| **Jan-11** | 8.326667 | 9 |
| **Feb-11** | 7.273333 | 9 |
| **Mar-11** | 6.664444 | 9 |

| **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|
| **January to February** | 1.0533333 | 0.414249781 | 1.4623 | **Means are not different** |
| **January to March** | 1.6622222 | 0.414249781 | 1.4623 | **Means are different** |
| **February to March** | 0.6088889 | 0.414249781 | 1.4623 | **Means are not different** |

Appendix PP14. Analysis of variance of secchi depth values in Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 14.3 | 1.588889 | 0.866111 |
| Transitional | 9 | 10.66 | 1.184444 | 0.173678 |
| Riverine | 9 | 8.15 | 0.905556 | 0.064028 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 2.124896 | 2 | 1.062448 | 2.887567 | ***0.075213*** | 3.402826 |
| Within Groups | 8.830533 | 24 | 0.367939 | | | |
| | | | | | | |
| Total | 10.95543 | 26 | | | | |

Appendix PP15. Analysis of variance of secchi depth values in Guajataca Reservoir by sampling dates

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Dec-10 | 9 | 10.71 | 1.19 | 0.41165 |
| Jan-11 | 9 | 12.5 | 1.388889 | 0.811111 |
| Feb-11 | 9 | 9.9 | 1.1 | 0.0975 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.393341 | 2 | 0.19667 | 0.44689 | ***0.644829*** | 3.402826 |
| Within Groups | 10.56209 | 24 | 0.440087 | | | |
| | | | | | | |
| Total | 10.95543 | 26 | | | | |

Appendix PP16. Analysis of variance of secchi disk values by sampling stations for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 9 | 11.1 | 1.233333 | 0.1125 |
| Transitional | 9 | 8.75 | 0.972222 | 0.054444 |
| Riverine | 9 | 5.55 | 0.616667 | 0.0275 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 1.72463 | 2 | 0.862315 | 13.30429 | ***0.000129*** | 3.402826 |
| Within Groups | 1.555556 | 24 | 0.064815 | | | |
| | | | | | | |
| Total | 3.280185 | 26 | | | | |

Appendix PP17. Analysis of variance of secchi disk values by sampling dates for La Plata Reservoir

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Jan-11 | 9 | 7.8 | 0.866667 | 0.041875 |
| Feb-11 | 9 | 7.8 | 0.866667 | 0.11 |
| Mar-11 | 9 | 9.8 | 1.088889 | 0.221111 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.296296 | 2 | 0.148148 | 1.191584 | ***0.321079*** | 3.402826 |
| Within Groups | 2.983889 | 24 | 0.124329 | | | |
| | | | | | | |
| Total | 3.280185 | 26 | | | | |

Appendix PP18. Tukey Kramer Multiple Comparisons of secchi depth means of La Plata Reservoir by sampling stations

| **Group** | **Sample Mean** | **Sample Size** | **Comparison** | Absolute Difference | Std. Error of Difference | Critical Range | **Results** |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 1.233333 | 9 | **Lacustrine to Transitional** | 0.2611111 | 0.084862513 | 0.2996 | **Means are not different** |
| **Transitional** | 0.972222 | 9 | **Lacustrine to Riverine** | 0.6166667 | 0.084862513 | 0.2996 | **Means are different** |
| **Riverine** | 0.616667 | 9 | **Transitional to Riverine** | 0.3555556 | 0.084862513 | 0.2996 | **Means are different** |

Appendix PP19. Analysis of variance of pH values in Guajataca Reservoir by sampling stations.

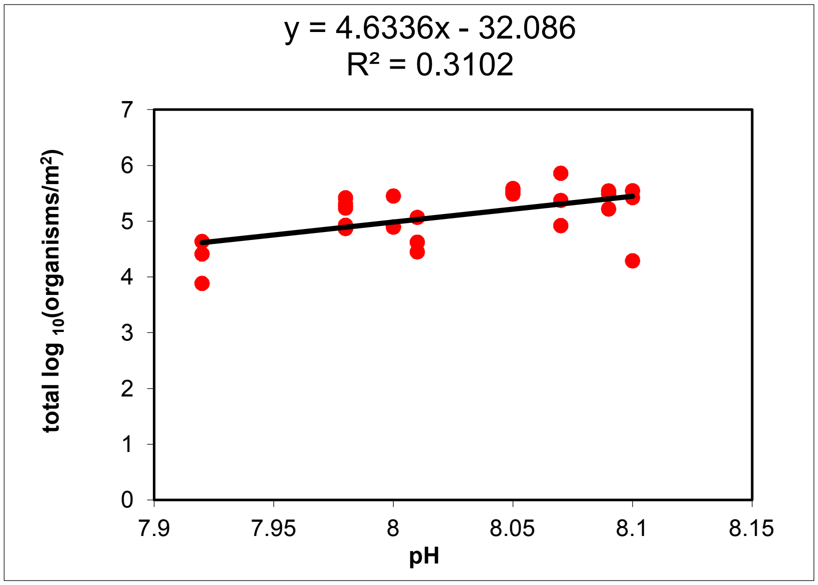
SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 2 | 16.02 | 8.01 | 0.0162 |
| Transitional | 3 | 24.21 | 8.07 | 0.0004 |
| Riverine | 3 | 23.96 | 7.986667 | 0.000133 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.010921 | 2 | 0.00546 | 1.581202 | ***0.293684*** | 5.786135 |
| Within Groups | 0.017267 | 5 | 0.003453 | | | |
| | | | | | | |
| Total | 0.028187 | 7 | | | | |

Appendix PP20. Correlation with pH values, Guajataca Reservoir




Appendix PP21. Analysis of variance of pH values by sampling stations for La Plata Reservoir

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Lacustrine | 3 | 25.6 | 8.533333 | 0.020233 |
| Transitional | 3 | 25.74 | 8.58 | 0.0036 |
| Riverine | 3 | 25.79 | 8.596667 | 0.005233 |

ANOVA

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 0.006467 | 2 | 0.003233 | 0.333716 | ***0.728749*** | 5.143253 |
| Within Groups | 0.058133 | 6 | 0.009689 | | | |
| | | | | | | |
| Total | 0.0646 | 8 | | | | |

Appendix PP22. Analysis of variance of Chl A in Guajataca Reservoir by sampling stations

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 7.856 | 2.618667 | 0.116932 |
| Transitional | 3 | 9.913 | 3.304333 | 0.232166 |
| Riverine | 3 | 13.23 | 4.41 | 3.578563 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 4.901513 | 2 | 2.450756 | 1.87192 | ***0.233487*** | 5.143253 |
| Within Groups | 7.855323 | 6 | 1.309221 | | | |
| | | | | | | |
| Total | 12.75684 | 8 | | | | |

Appendix PP23. Analysis of variance of Chl A concentrations by sampling stations for La Plata Reservoir

SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Lacustrine | 3 | 45.2 | 15.06667 | 2.613333 |
| Transitional | 3 | 208.2 | 69.4 | 5508.07 |
| Riverine | 3 | 166.4 | 55.46667 | 210.5633 |

ANOVA

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 4778.409 | 2 | 2389.204 | 1.252806 | ***0.351024*** | 5.143253 |
| Within Groups | 11442.49 | 6 | 1907.082 | | | |
| | | | | | | |
| Total | 16220.9 | 8 | | | | |

Appendix PP24. Analysis of variance of total phosphorus concentration for Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 0.025086 | 0.008362 | 3.17E-06 |
| Transitional | 3 | 0.01885 | 0.006283 | 1.48E-07 |
| Riverine | 3 | 0.03113 | 0.010377 | 7.88E-07 |

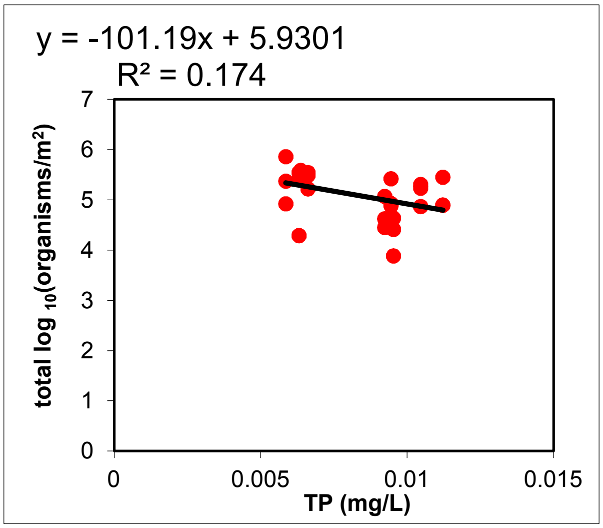
ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 2.51E-05 | 2 | 1.26E-05 | 9.173735 | ***0.01496<br>6*** | 5.14325<br>3 |
| Within Groups | 8.22E-06 | 6 | 1.37E-06 | | | |
| | | | | | | |
| Total | 3.34E-05 | 8 | | | | |

Appendix PP25. Tukey Kramer Multiple Comparisons of total phosphorus means for Guajataca Reservoir

| Group | Sample Mean | Sample Size | Comparison | Absolute Difference | Std. Error of Difference | Critical Range | Results |
|---|---|---|---|---|---|---|---|
| **Lacustrine** | 0.008362 | 3 | **Lacustrine to Transitional** | 0.0020785 | 0.000675754 | 0.0029 | **Means are not different** |
| **Transitional** | 0.006283 | 3 | **Lacustrine to Riverine** | 0.0020148 | 0.000675754 | 0.0029 | **Means are not different** |
| **Riverine** | 0.010377 | 3 | **Transitional to Riverine** | 0.0040933 | 0.000675754 | 0.0029 | **Means are different** |

Appendix PP26. Correlation with TP concentrations, Guajataca Reservoir

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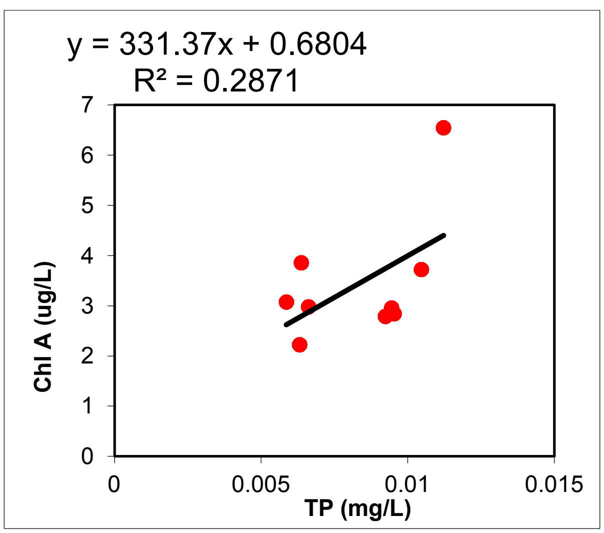
Appendix PP27. Correlation between TP and Chl A concentrations.

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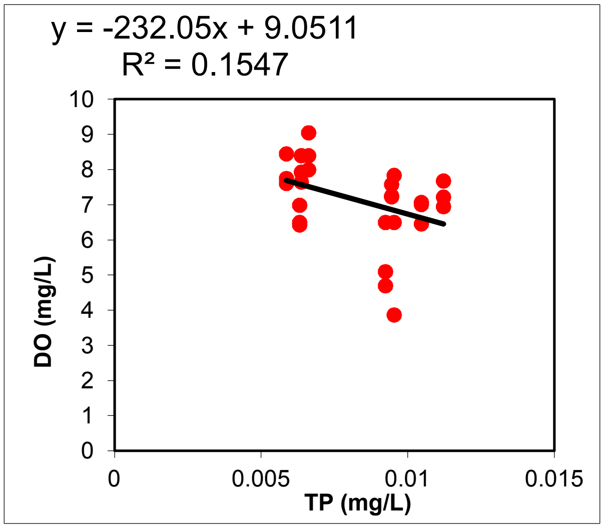
Appendix PP28. Correlation between TP and DO concentrations Guajataca Reservoir.




Appendix PP29. Analysis of variance of total phosphorus concentrations by sampling stations for La Plata Reservoir

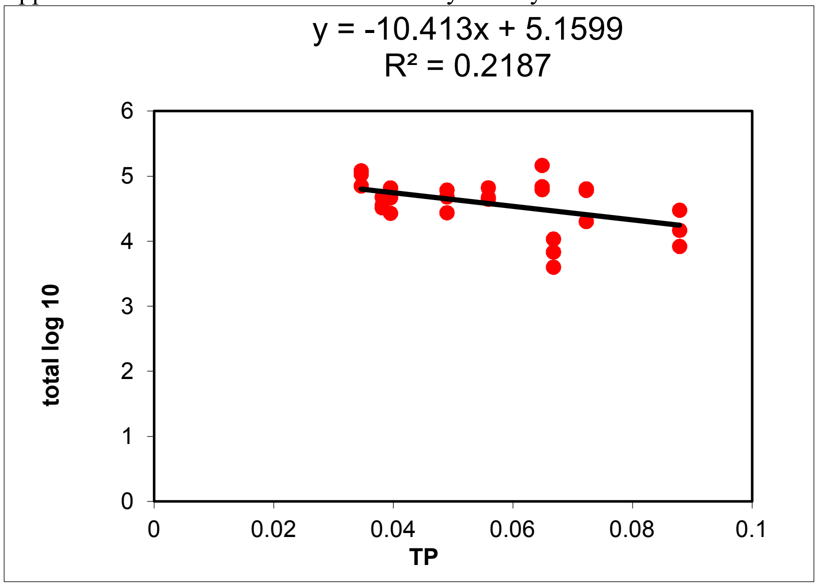
SUMMARY

| Groups | Count | Sum | Average | Variance |
|---|---|---|---|---|
| Lacustrine | 3 | 0.126619 | 0.042206 | 3.47E-05 |
| Transitional | 3 | 0.162773 | 0.054258 | 0.000356 |
| Riverine | 3 | 0.219541 | 0.07318 | 0.000163 |

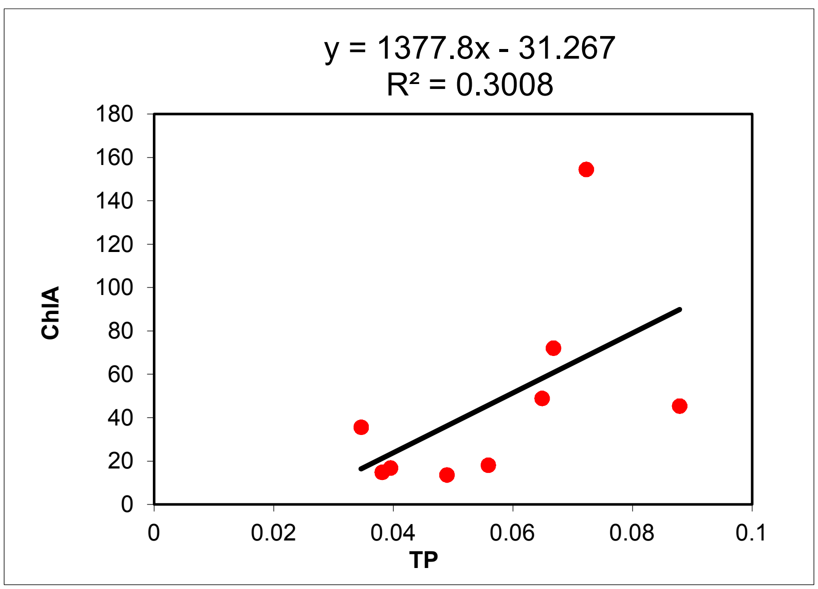
ANOVA

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 0.001463 | 2 | 0.000731 | 3.960185 | ***0.080076*** | 5.143253 |
| Within Groups | 0.001108 | 6 | 0.000185 | | | |
| | | | | | | |
| Total | 0.002571 | 8 | | | | |

Appendix PP30. Correlation of community density and TP concentrations.




Appendix PP31. Correlation of Chl A and TP concentrations.



Appendix PP32. Analysis of variance of total kjeldahl nitrogen concentrations for Guajataca Reservoir by sampling stations.

SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 1.815936 | 0.605312 | 0.058816 |
| Transitional | 3 | 2.292253 | 0.764084 | 0.494061 |
| Riverine | 3 | 1.113236 | 0.371079 | 0.002581 |

ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.234527 | 2 | 0.117264 | 0.633335 | ***0.562921*** | 5.143253 |
| Within Groups | 1.110916 | 6 | 0.185153 | | | |
| | | | | | | |
| Total | 1.345444 | 8 | | | | |

Appendix PP33. Analysis of variance of total kjeldahl nitrogen concentrations by sampling stations for La Plata Reservoir

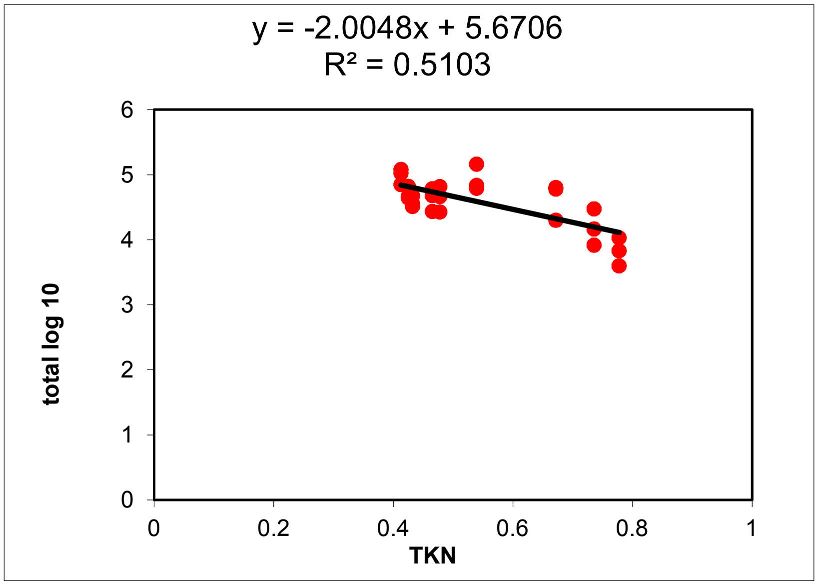
SUMMARY

| *Groups* | *Count* | *Sum* | *Average* | *Variance* |
|---|---|---|---|---|
| Lacustrine | 3 | 1.374737 | 0.458246 | 0.000557 |
| Transitional | 3 | 1.50947 | 0.503157 | 0.021337 |
| Riverine | 3 | 2.052139 | 0.684046 | 0.016176 |

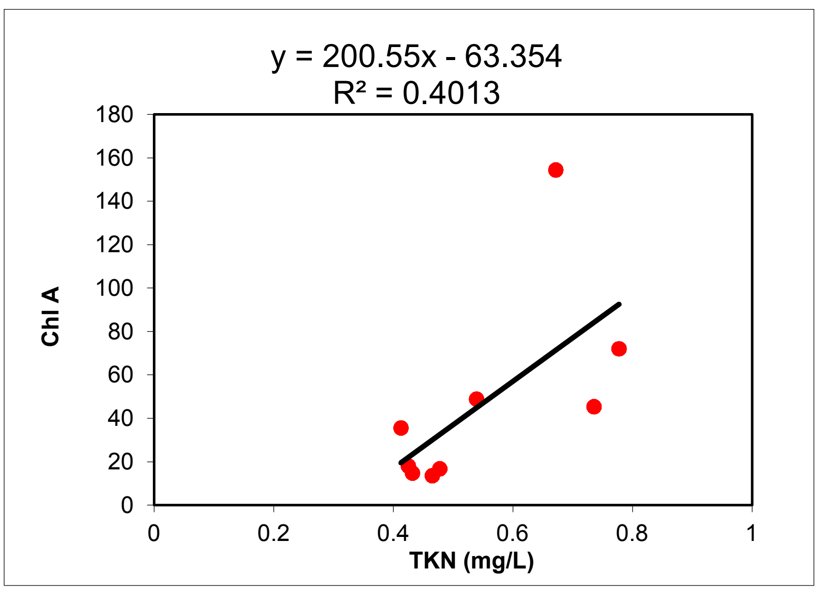
ANOVA

| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
|---|---|---|---|---|---|---|
| Between Groups | 0.085724 | 2 | 0.042862 | 3.377644 | ***0.104084*** | 5.143253 |
| Within Groups | 0.076139 | 6 | 0.01269 | | | |
| | | | | | | |
| Total | 0.161863 | 8 | | | | |

Appendix PP34. Correlations of Community density and TKN concentrations




Appendix PP35. Correlations of ChlA and TKN concentrations.

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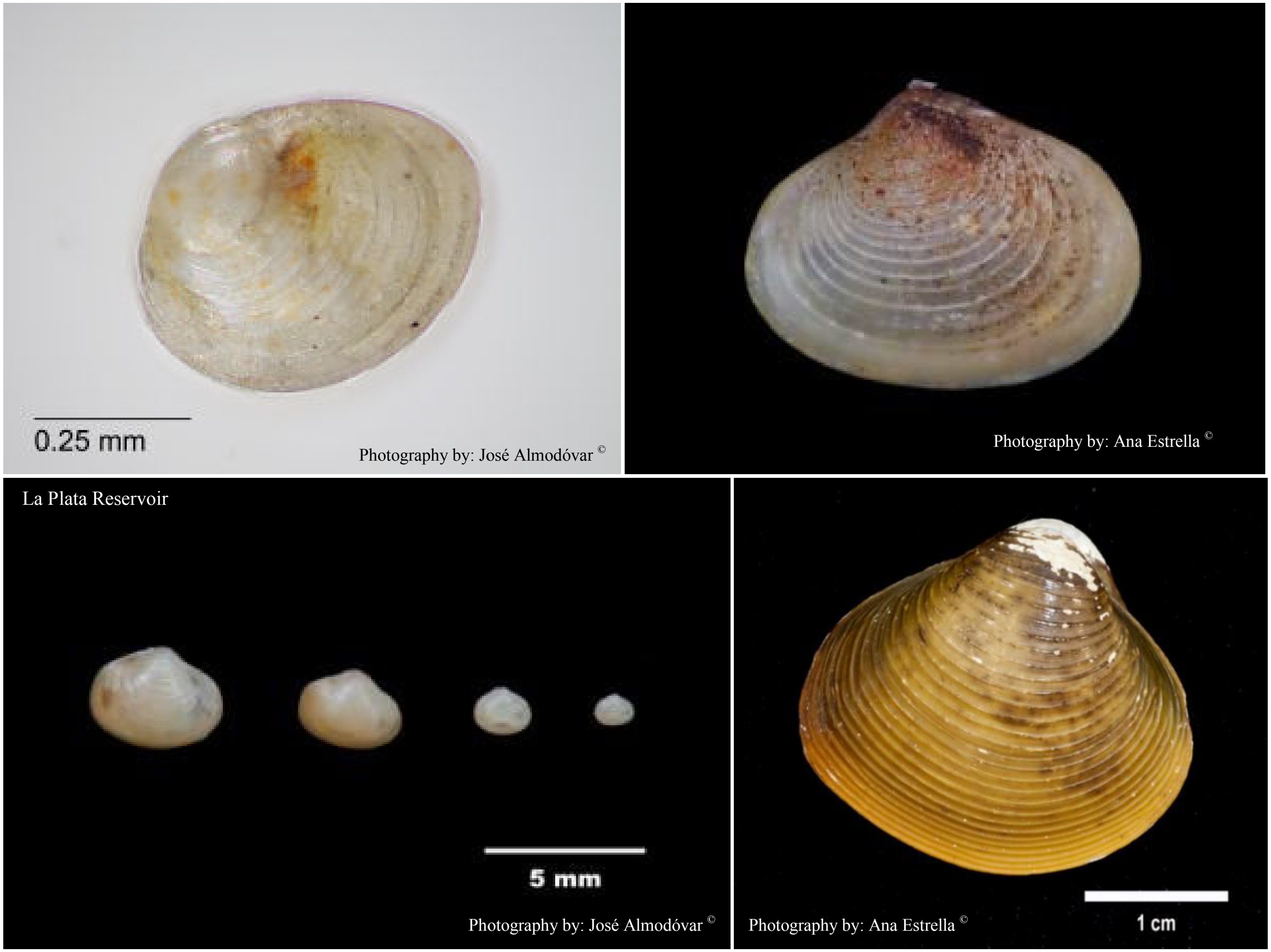
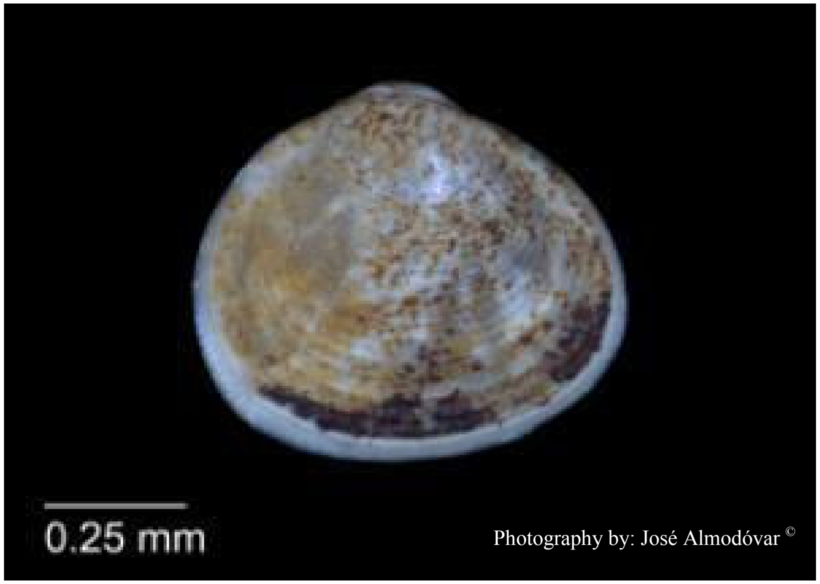
# Pictures of Benthic Invertebrates Found in this study

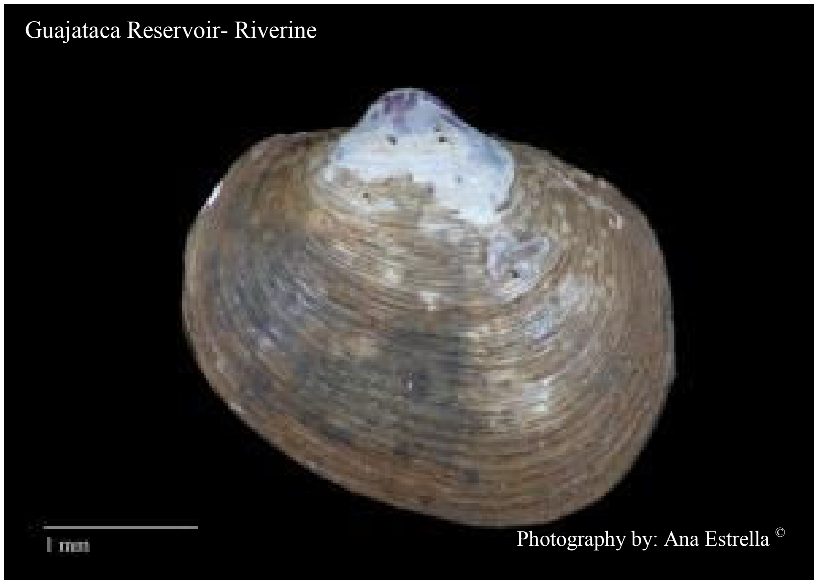
*Corbicula fluminea*



*Pisidium casertanum*




*Eupera cf. portoricensis*




*Tarebia granifera*





*Melanoides tuberculata*



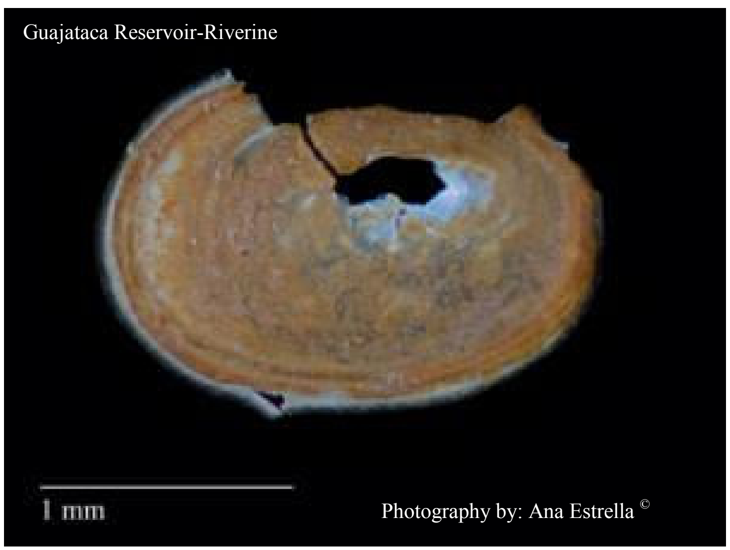
cf *Brotia costula*


*Aylacostoma* cf. *pulcher*


*Gundlachia radiata*



*Ferrissia* cf. *fragilis*

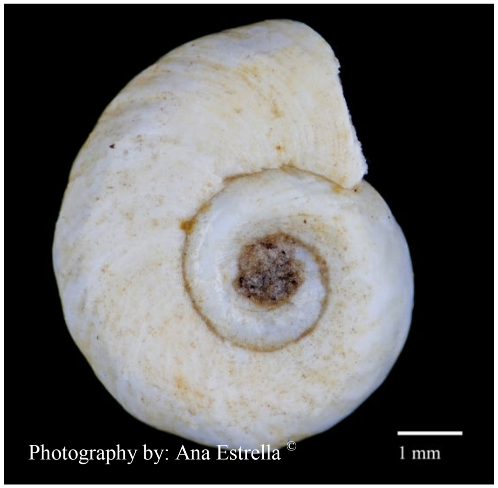



*Ferrissia irrorata*

*Menetus dilataus*



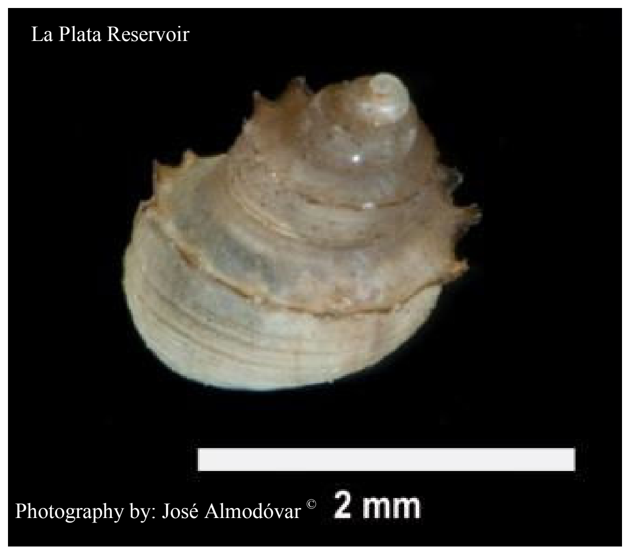
*Planorbella sp.*

*Pyrgophorus coronatus*




*Pyrgoporus parvulus*

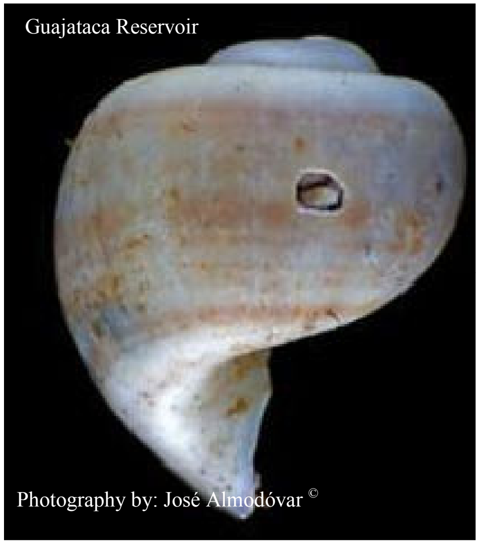



*Potamopyrgus antipodarum*



Complex *Pyrgophorus/Potamopyrgus:* left *P. antipodarum*, center *P. parvulus* and right *P. coronatus*

*Pomacea cumingi*





*Marisa cornuarietis*


*Amnicola* cf. *sp. (compare to Drymaeus; terrestrial)*


*Physa marmorata*

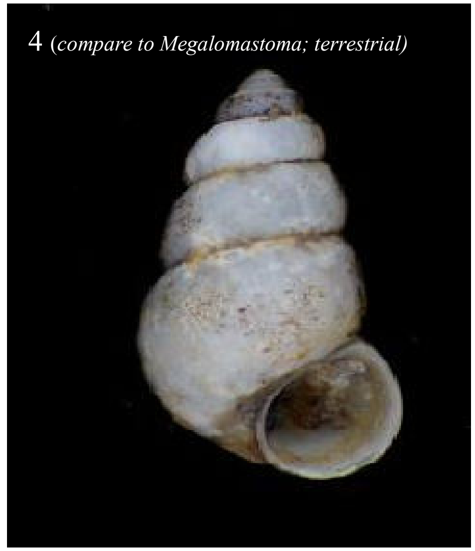

cf *Elimia sp.*

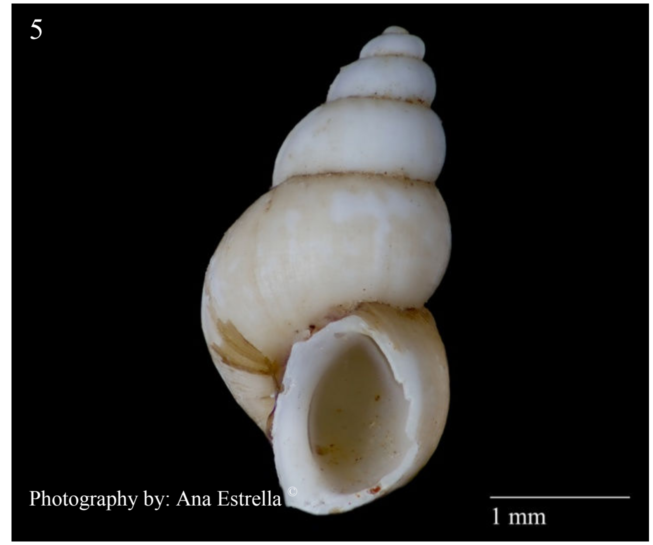


Unknown species

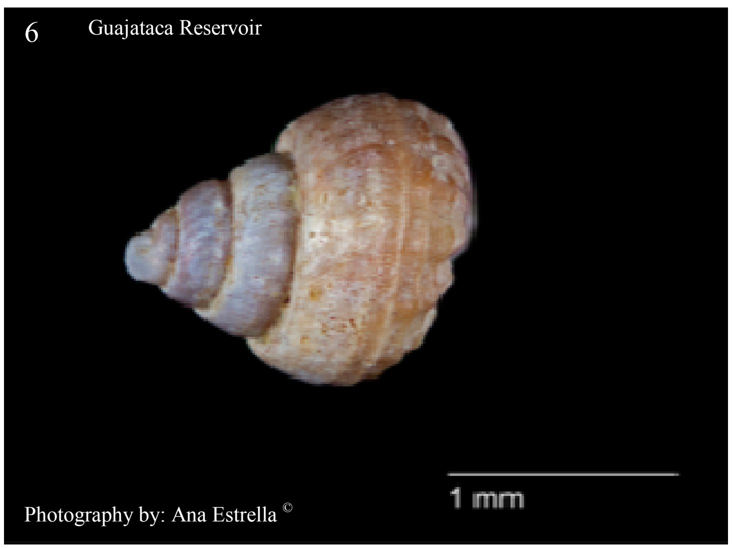



3 *(possibly terrestrial)*


4 *(compare to Megalomastoma; terrestrial)*



5



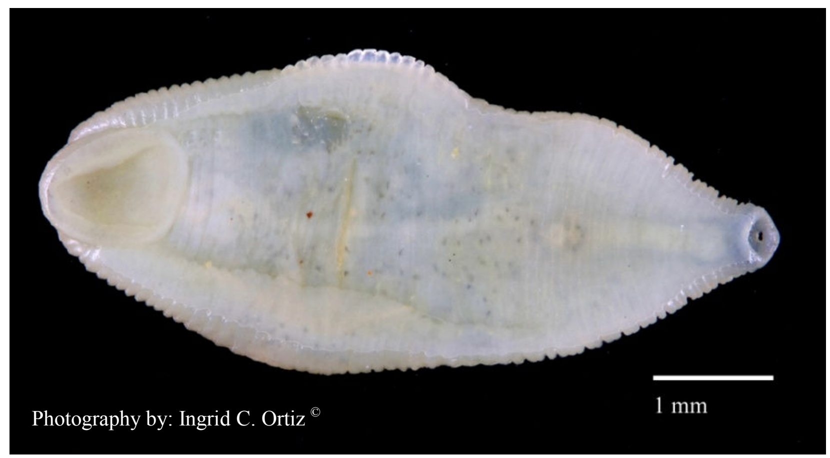
6 Guajataca Reservoir

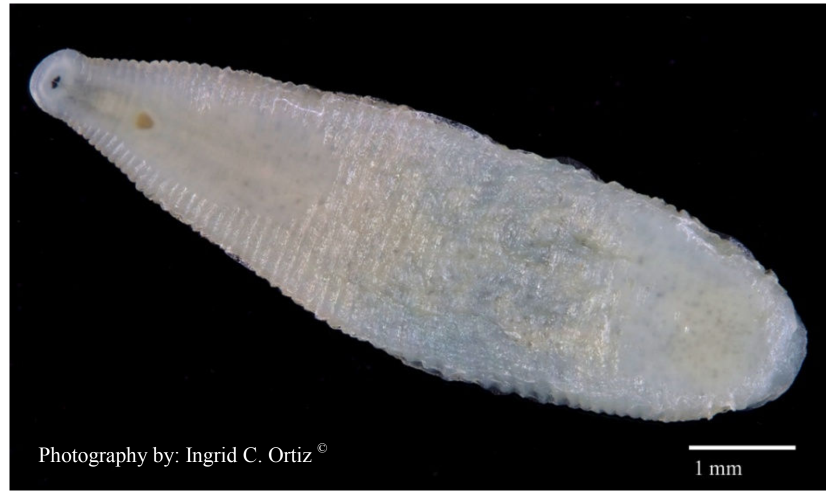
6 Guajataca Reservoir

Chironomidae



Hirudinea

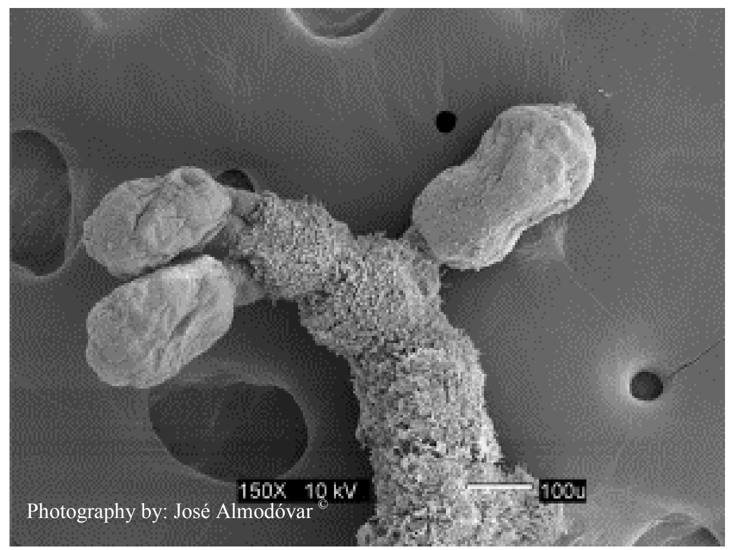

*Urnatella gracilis* (colony)


*Urnatella gracilis* colony over gasteropod


*Urnatella gracilis* (stalk)

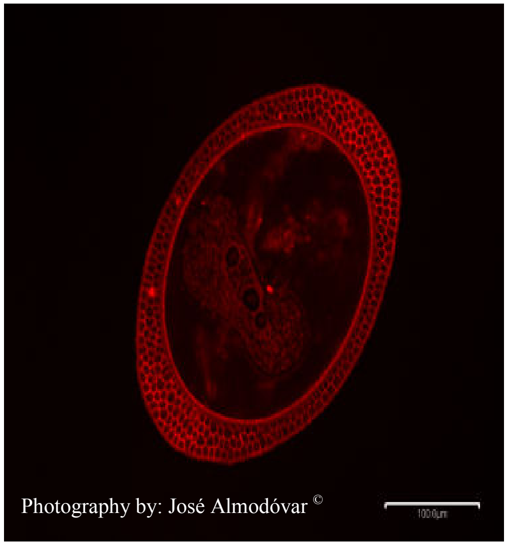

Phase contrast microscopy

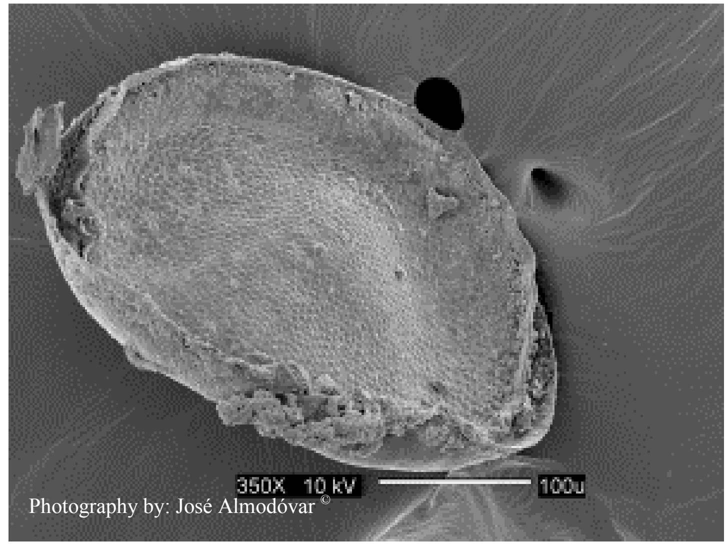

Scanning electron microscopy (SEM)

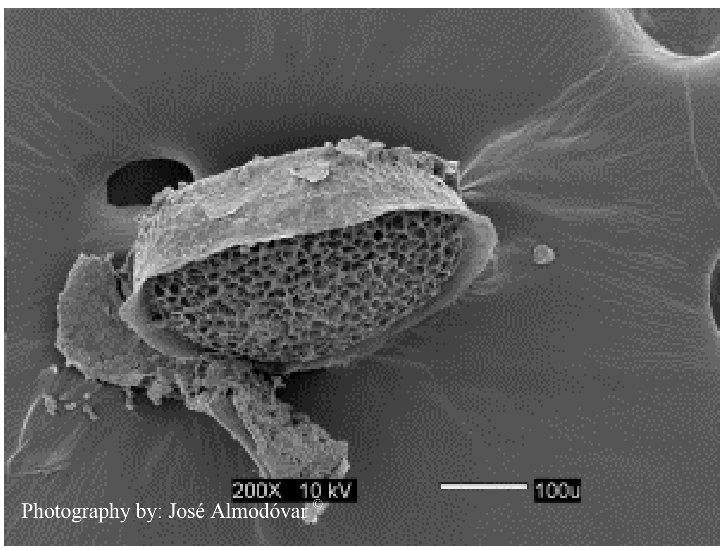


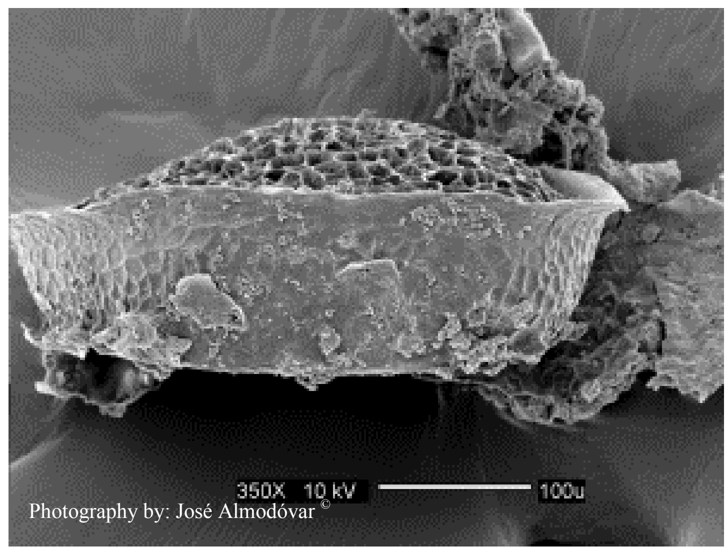
*Plumatella repens* Statoblast -Fluorescence microscopy

SEM

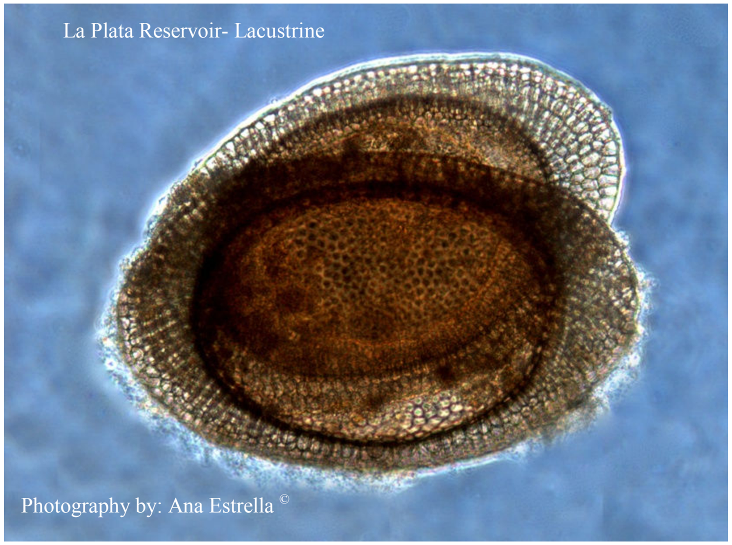


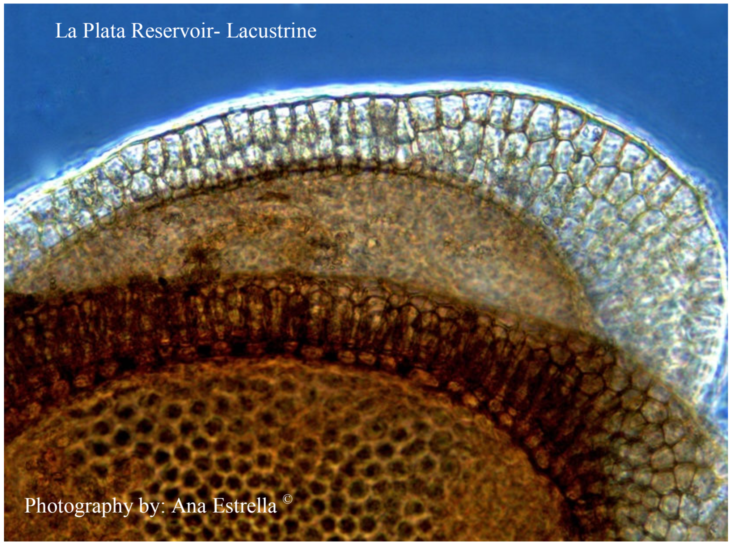



Phase contrast microscope

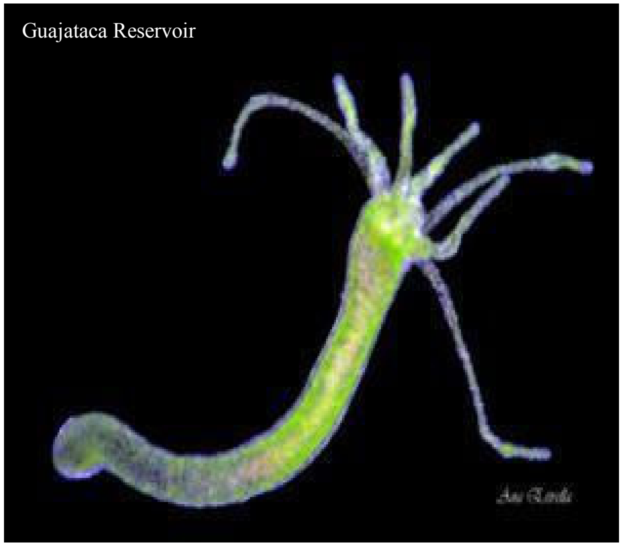


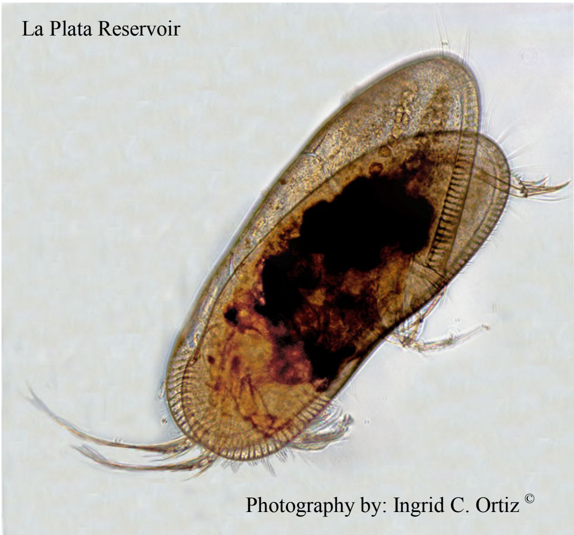
*Hydra vulgaris* Dark field microscope



*Hydra viridis*

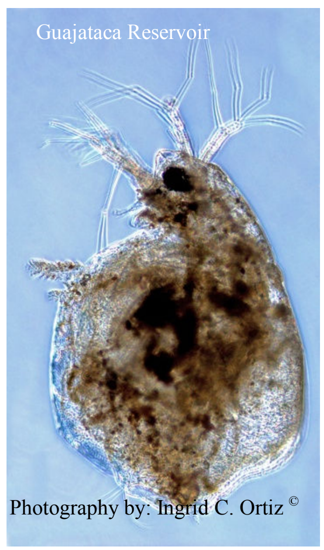


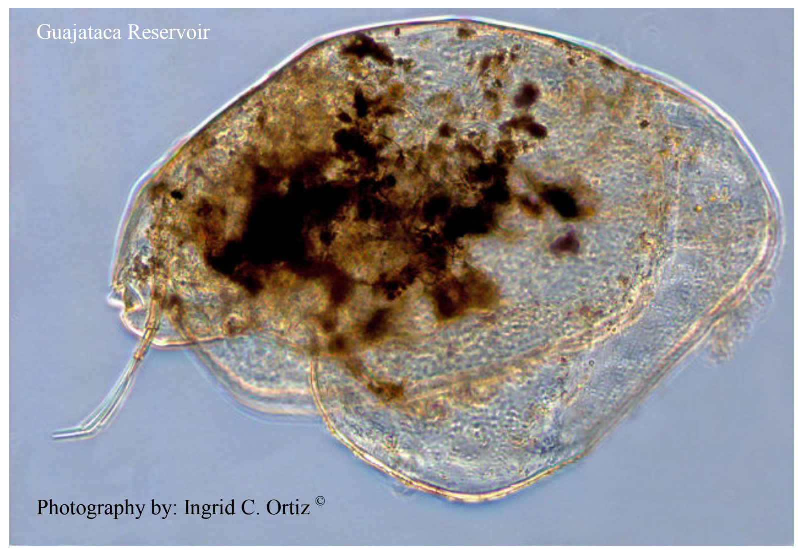

Ostracoda: *Stenocypris sp.* *Hemicypris ? sp.*





Cladocera: *Kurzia polyspina* *Simocephalus sp.* Unknown chydorid

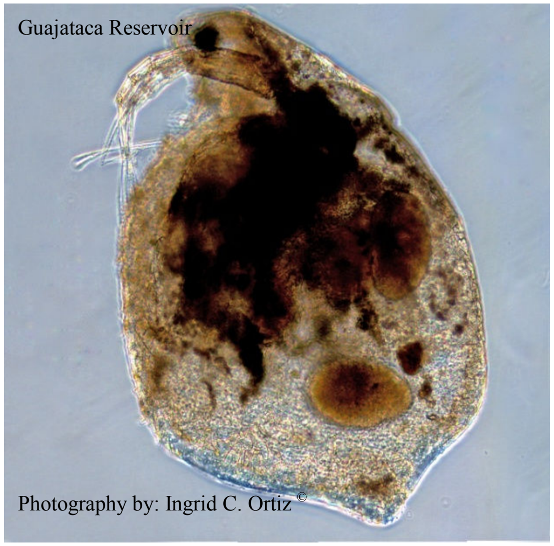



*Ilyocryptus spinifer*


*Simocephalus sp.*

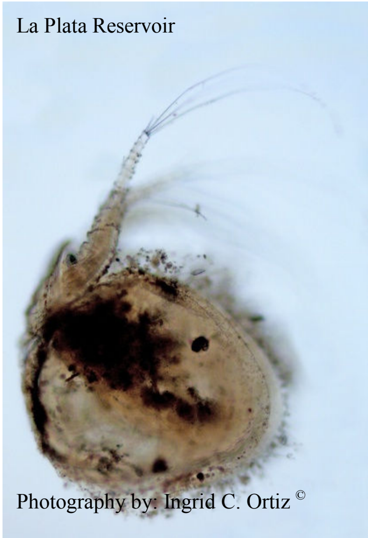

*Simocephalus sp.*


*Simocephalus sp.*




*Simocephalus sp.*


*Ilyocryptus sp.*



*Hyalella azteca*

# Pictures of the Study Sites and Procedures

Guajataca Reservoir

Littoral zone of the lacustrine station

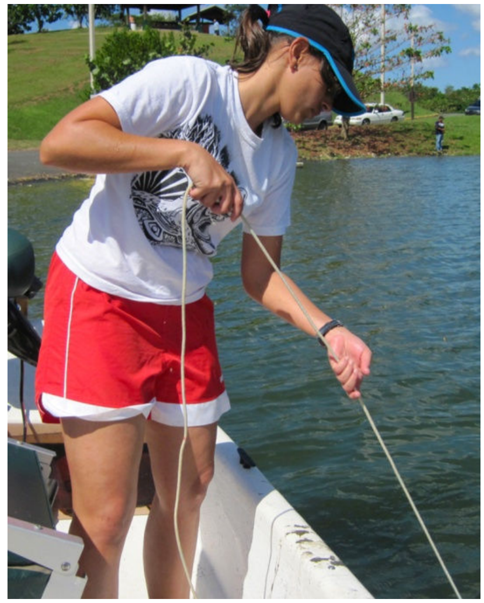
Littoral zone of the transitional station

Littoral zone of the riverine station

*Corbicula fluminea* in the shore

La Plata Reservoir

Samples collection with an Ekman dredge

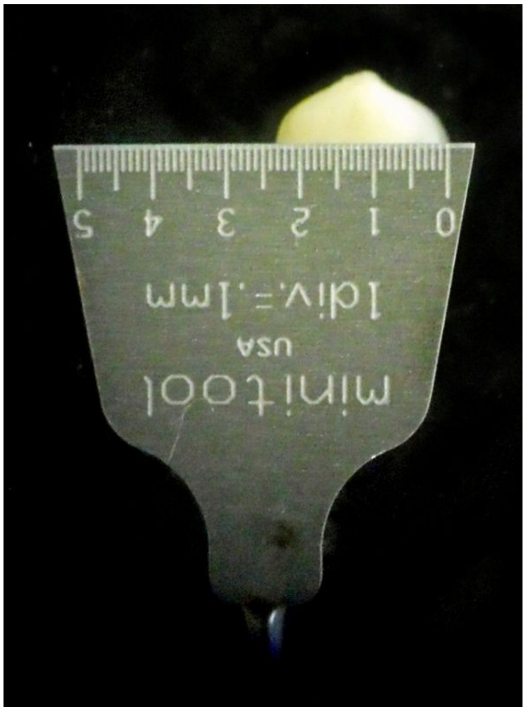


Field instrumentation

Laboratory work

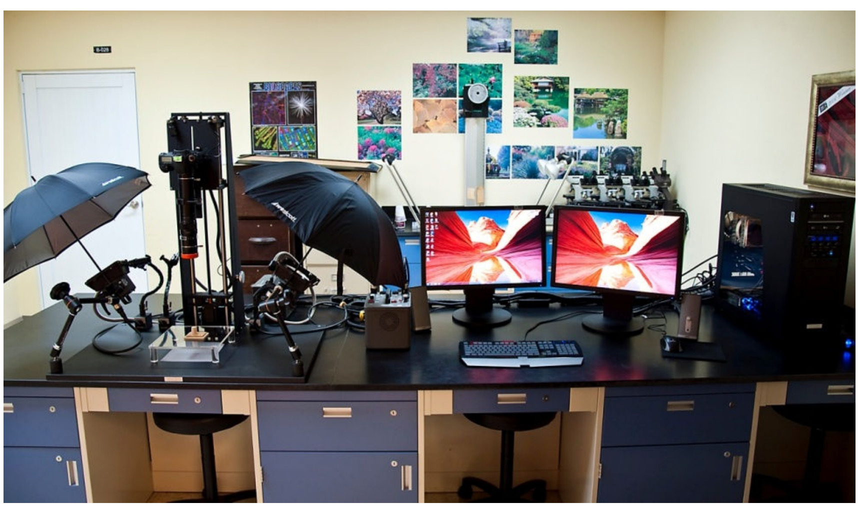
Samples

*C. fluminea* measurements





Visionary Digital Integrated Systems©



Sediments classification instrumentation